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AVRADCOM

Technical Report TR 83-F-8

AD

AD-A146 394

MANUFACTURING METHODS AND TECHNOLOGY (MANTECH) PROGRAM

HYBRID ELASTOMERIC SEALS

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MARCH 1983 **FINAL REPORT**

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: USAAVRADCOM TR 83-F-8	2. GOVT ACCESSION NO.: AD-A145 394
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): HYBRID ELASTOMERIC SEALS MM&T PROGRAM	5. TYPE OF REPORT & PERIOD COVERED: Final Report August 1978-November 1982
	6. PERFORMING ORG. REPORT NUMBER: MTI 82TR23
7. AUTHOR(s): Martin W. Eusepi	8. CONTRACT OR GRANT NUMBER(s): NAS3-20837
9. PERFORMING ORGANIZATION NAME AND ADDRESS: MECHANICAL TECHNOLOGY INCORPORATED Latham, New York 12110	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 1777108 1497 004 1817108 1497 004
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Aviation Research and Development Command Attn: DRDAV-EGX 4300 Goodfellow Blvd; St. Louis, MO 63120	12. REPORT DATE: March 1983
	13. NUMBER OF PAGES: 102
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): US Army Propulsion Laboratory AVRADCOM Research & Technology Laboratories Joint w/NASA Lewis, Cleveland, OH 44135	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release. Distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Seal - oil-to-air
Seal - transmission input
Seal - hybrid elastomer
Seal - high-speed

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Manufacturing technology has been developed for the production of the Hybrid Elastomer Liquid-to-Gas Type Seal. This seal type consists of a series of carbon ring elements inserted in an elastomer member resembling a lip seal. Manufacturing tooling and molds were fabricated with the capability of producing 500 to 1000 units. Two seal sizes were fabricated and assembled; their diameters were 63.50 mm (2.500 in.) and 139.2 mm (5.481 in.). Nine of the large-diameter seals were tested at the following matrix.

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20. ABSTRACT (Continued)

of nine conditions:

Surface Speeds	Shaft Runout	Seal Pressure
50.8 m/s (10,000 ft/min)	0.025 mm	0.0 N/cm^2
76.2 m/s (15,000 ft/min)	(0.001 in.)	6.9 x 10^{-3} N/m^2 (1.0 psig)
101.6 m/s (20,000 ft/min)		1.4 x 10^{-2} N/m^2 (2.0 psig)

Seal torque and seal leakage at the various operating conditions were determined. Leakage rates varied between 1.9 cc/hr and 400 cc/hr, friction torque varied between 1.5 N·m (1.1 ft-lb) and 3.7 N·m (2.7 ft-lb); and wear rates up to 0.010 mm/hr (0.0004 in./hr) were measured.

18. SUPPLEMENTARY NOTES

This project was accomplished as part of the U.S. Army Aviation Research and Development Command Manufacturing Technology program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use in production of Army material. Comments are solicited on the potential utilization of the information contained herein as applied to present and/or future production programs. Such comments should be sent to: U.S. Army Aviation Research and Development Command, ATTN: DRDAV-EGX, 4300 Goodfellow Blvd., St. Louis, MO 63120.

The work described in this report was accomplished under a contract monitored jointly by the U.S. Army Propulsion Laboratory of AVRADCOM Research and Technology Laboratories, with contracting services provided by the NASA Lewis Acquisition Division. The U.S. Army Propulsion Laboratory administered the contract; NASA Lewis provided technical direction through Messrs. Lawrence Ludwig and Gordon Allen.

TABLE OF CONTENTS

SECTION		PAGE
	LIST OF FIGURES	3
	LIST OF TABLES	5
1.0	SUMMARY	7
2.0	INTRODUCTION	9
3.0	SEAL AND DESIGN FABRICATION	11
	3.1 Seal Design	11
	3.2 Seal Manufacture	11
	3.2.1 Carbon Graphite Seal Rings	11
	3.2.2 Molded Elastomer	11
	3.3 Garter Springs	20
	3.4 Component Inspection	20
	3.5 Seal Assembly	20
4.0	SEAL TESTING	25
	4.1 Seal Testing Program	25
	4.1.1 Seal Inspection and Seal Rework	25
	4.1.2 Data Collection	27
	4.2 Seal Test Apparatus	27
	4.2.1 Seal Contact Pressure Tester	27
	4.2.2 Static Tester	28
	4.2.3 Dynamic Tester	28
5.0	TEST RESULTS	35
	5.1 Test on the Small-Diameter Seal	35
	5.2 Test on the Large-Diameter Seal	35
	5.2.1 Static Tests	35
	5.2.2 Dynamic Tests	36
6.0	DISCUSSION OF TEST RESULTS	49
7.0	CONCLUSIONS	53
8.0	REFERENCES	55

TABLE OF CONTENTS (Cont'd)

SECTION		PAGE
APPENDIX A	LIST OF DRAWINGS	57
APPENDIX B	INSPECTION REPORTS - STATIC TESTING OF SMALL-DIAMETER SEALS	61
APPENDIX C	INSPECTION REPORTS - STATIC TESTING OF LARGE-DIAMETER SEALS	75
APPENDIX D	PROPOSED PROCESS SPECIFICATION FOR THE PRODUCTION OF ELASTOMERIC-HYBRID SEALS	95

LIST OF FIGURES

NUMBER		PAGE
1	Cross Section of Hybrid Elastomer Seal	12
2	Typical Seal Segment	14
3	Photograph of Seal Segment	15
4	Molded Elastomer Cross Section	17
5	Components for Single-Cavity Injection Mold	18
6	Elastomer Cross Section.	19
7	Schematic of Carbon Ring Installation Fixture.	21
8	Photograph of Carbon Ring Installation Fixture	22
9	Garter Spring Insertion Tool	24
10	Radial-Force Gage	29
11	Force Gage Calibration Curve	30
12	Static Seal Tester	31
13	Seal Test Rig Cross Section.	32
14	Installed Seal Test Rig.	33
15	Hybrid Elastomer Seal (No. 8) Runner Contact Force . . .	38
16	Hybrid Elastomer Seal (No. 9) Runner Contact Force . . .	39
17	Hybrid Elastomer Seal (No. 10) Runner Contact Force. . .	40
18	Hybrid Elastomer Seal (No. 11) Runner Contact Force. . .	41
19	Hybrid Elastomer Seal (No. 12) Runner Contact Force. . .	42
20	Hybrid Elastomer Seal (No. 14) Runner Contact Force. . .	43
21	Hybrid Elastomer Seal (No. 16) Runner Contact Force. . .	44
22	Hybrid Elastomer Seal (No. 17) Runner Contact Force. . .	45
23	Close-up of Shaft Seal Contact Area	50

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LIST OF TABLES

NUMBER		PAGE
1	MATERIALS OF CONSTRUCTION	13
2	DYNAMIC TESTING: TEST MATRIX	26
3	STATIC TEST RESULTS - LARGE-DIAMETER SEAL	37
4	SEAL FORCE MEASUREMENT RESULTS	46
5	DYNAMIC TEST RESULTS - SURFACE FINISH AND WEAR	47
6	DYNAMIC TEST RESULTS - LEAK RATE AND FRICTION TORQUE	48

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1.0 SUMMARY

Manufacturing technology has been developed for the production of hybrid elastomer seals to be used as input seals for current and advanced helicopter transmissions. Methods for manufacturing and assembling the seal components have proven successful and can be employed for lot sizes of 500 to 1000 units without modification. Two seals were chosen to represent the range of sizes presently used in the application of elastomeric lip seals. These seals were examined under this program to formulate the necessary manufacturing techniques and processes. A 139.2 mm (5.481 in.) diameter bore seal as found on the UH-1 helicopter, and a 63.5 mm (2.500 in.) diameter bore seal as found on the OH-58 helicopter were studied to accomplish the initial program objectives.

The elastomer molding effort was carried out under MTI supervision by the Irving B. Moore Corporation, a well-known rubber molding firm located in Cambridge, Massachusetts. The molding technique, which incorporated a multipiece injection mold, demonstrated production in lots of 500 to 1000 to be practical. The molding process produced an excellent bond joint between the steel housing and elastomer that did not leak nor delaminate under stress due to pressure and torsion.

In conjunction with the Stein Seal Company of Philadelphia, Pennsylvania, a manufacturing technique for producing the carbon graphite sealing segment insert proved successful for the 500- to 1000-unit production lot.

Seal garter springs were manufactured by York Spring Co. of South Elgin, Illinois.

After the successful production of the molded elastomers and carbon ring inserts, specialized assembly tools were constructed to permit rapid and accurate insertion of the carbon rings into the elastomers.

Lastly, the assembled seals were subjected to a test program to evaluate their performance under both static (nonrotating) and dynamic (rotating) conditions. Static seal tests were conducted to determine seal contact percent and air leakage rates. Dynamic tests were conducted at rubbing velocities of 50.8, 76.2,

and 102 m/s (10,000, 15,000, 20,000 ft/min) at differential pressures of 0, 6.9×10^{-3}, and 1.4×10^{-2} MPa (0, 1, 2 psi). A seal runner TIR of 0.025 mm (0.001 in.) was used throughout the tests.

Seal leakage rates ranged from a low of 1.9 cc/hr to as high as 400 cc/hr with friction torque varying from 1.5 N.m (1.1 ft-lb) to 3.7 N.m (2.7 ft-lb). Wear rates from a low of 0 to a high of 0.010 mm/hr (0.0004 in./hr) were measured.

Seal leakage is attributed primarily to the extreme test requirements of direct oil jet impingement which is much more severe than actual operating conditions. A contributing factor for the seal leakage lies in the carbon ring design. The tapered bore wore away rapidly, producing wear debris which collected between the seal's carbon elements, thereby producing leakage paths. A change from tapered bore to wind-back grooves in the carbon element design would substantially improve the oil retention capability of the seal without affecting the results of the manufacturing technology study reported herein.

2.0 INTRODUCTION

The overall objective of the work described herein was to develop the manufacturing technology for a NASA-invented, hybrid elastomeric seal employing segmented carbon rings carried in an otherwise elastomeric lip seal structure [1]*.

Elastomeric lip seals are, in general, a low-cost, effective means of sealing transmission shafts where the pressure difference is moderate. However, where the input shaft speed is high, as in advanced helicopter transmissions, high surface velocities may result in early failure of the simple lip seal, leading to early removal of transmissions for replacement. Since carbon rubbing surfaces perform much better than lip seals at higher surface velocities, NASA-Lewis designed a seal that would retain most of the low-cost advantages of an elastomeric lip seal and would yield high performance by incorporating carbon rings as the rubbing surface. A design constraint for the hybrid elastomeric seal was that it must be a direct replacement for presently used lip seals.

Installation of segmented rings into an elastomeric member eliminates much of the precision machining of the mechanical seal, allows antirotation features to be obtained without additional machining operations, and minimizes the envelope size. The purpose of this manufacturing program was to develop processes and techniques for fabricating the carbon ring segments and molding the elastomeric element to accommodate the segments, and to develop means to assemble the seal components.

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*Numbers in brackets indicate references listed in Section 8.0.

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3.0 SEAL DESIGN AND FABRICATION

3.1 Seal Design

The hybrid elastomer seal [2,3] had evolved into the configuration represented by NASA drawings CC853227 and CD853998. Final production drawings for both the large and small seals are found at the end of the report, a list of these drawings is provided in Appendix A. A representative cross section of the seal evaluated in this program is illustrated in Figure 1. The seal components consist of an outer seal ring housing to which is bonded an elastomer seal body. The seal body incorporates internal cavities sized to accept the segmented carbon graphite seal rings. Six antirotation stops are molded into the elastomer; three equally spaced for the oil-side carbon ring segments, and three equally spaced for the air-side segments, with one set offset 60° from the other. Two garter springs and an inner seal ring housing used for garter spring containment complete the seal assembly. Table 1 lists the seal components, their materials of construction and treatment.

3.2 Seal Manufacture

3.2.1 Carbon Graphite Seal Rings

Each assembled seal includes two three-segment, carbon graphite seal rings placed back-to-back. All segments are fabricated as a set according to the dimensions found on the detailed part drawings 399D05 and 399D08 and illustrated on Figure 2. The seal rings were manufactured using normal production tooling capable of providing acceptable piece parts in production lot quantities of 500 to 1000 total seal sets. A photograph of carbon ring segments is shown in Figure 3.

3.2.2 Molded Elastomer

The only difficult seal component to manufacture was the molded elastomer. In reviewing the design from the standpoint of manufacturing technology, MTI and its team members concluded that the carbon segments were too slender and fragile to survive the rubber molding process if they were to be included in the mold.

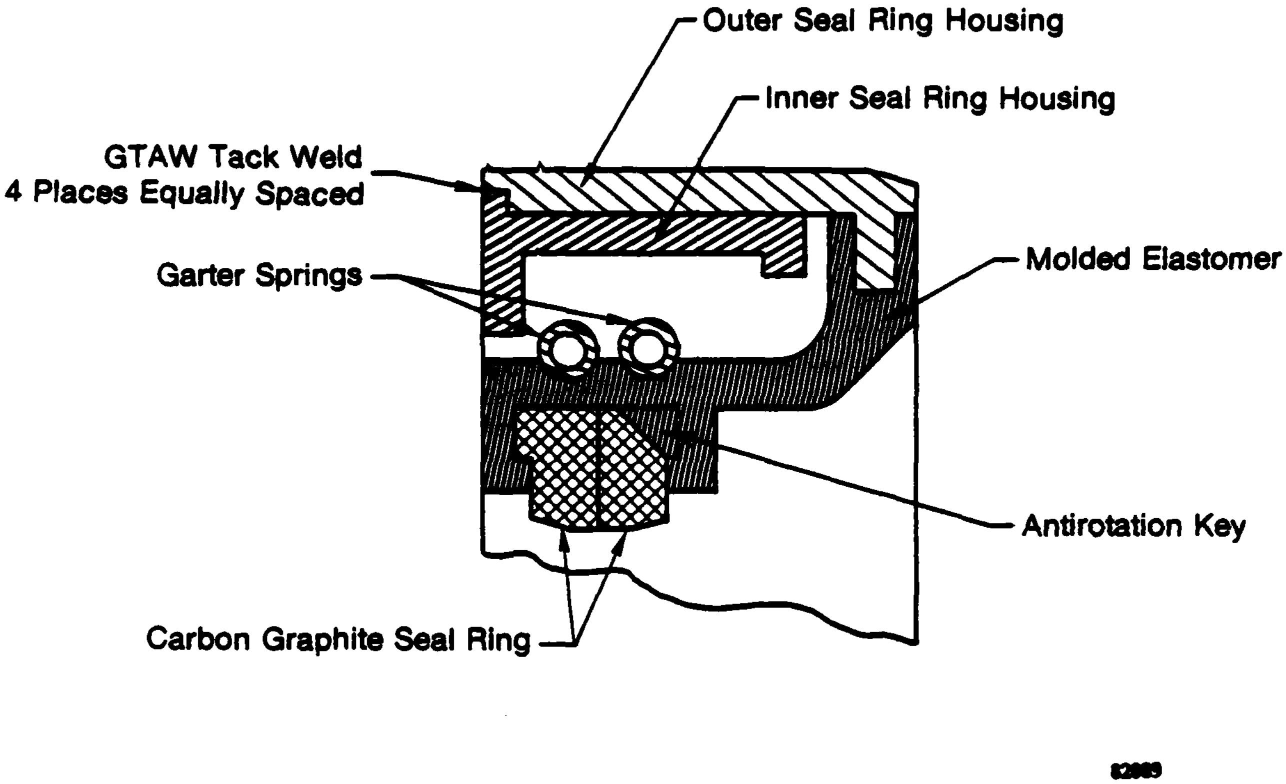

Figure 1. Cross Section of Hybrid Elastomer Seal.

TABLE 1. MATERIALS OF CONSTRUCTION

Component	Material	Treatment
Outer Seal Ring Housing Inner Seal Ring Housing	AISI Type 1018 Cold Drawn Seamless Tubing	Full Anneal, Black Oxide* Per AMS-2485
Molded Elastomer	MIL-R-83248 Fluorcarbon 70 Durometer	None
Seal Rings	Pure Carbon P-25	None
Garter Springs	AISI Type 302-304 Stainless Tubing	None

*Performed after molding.

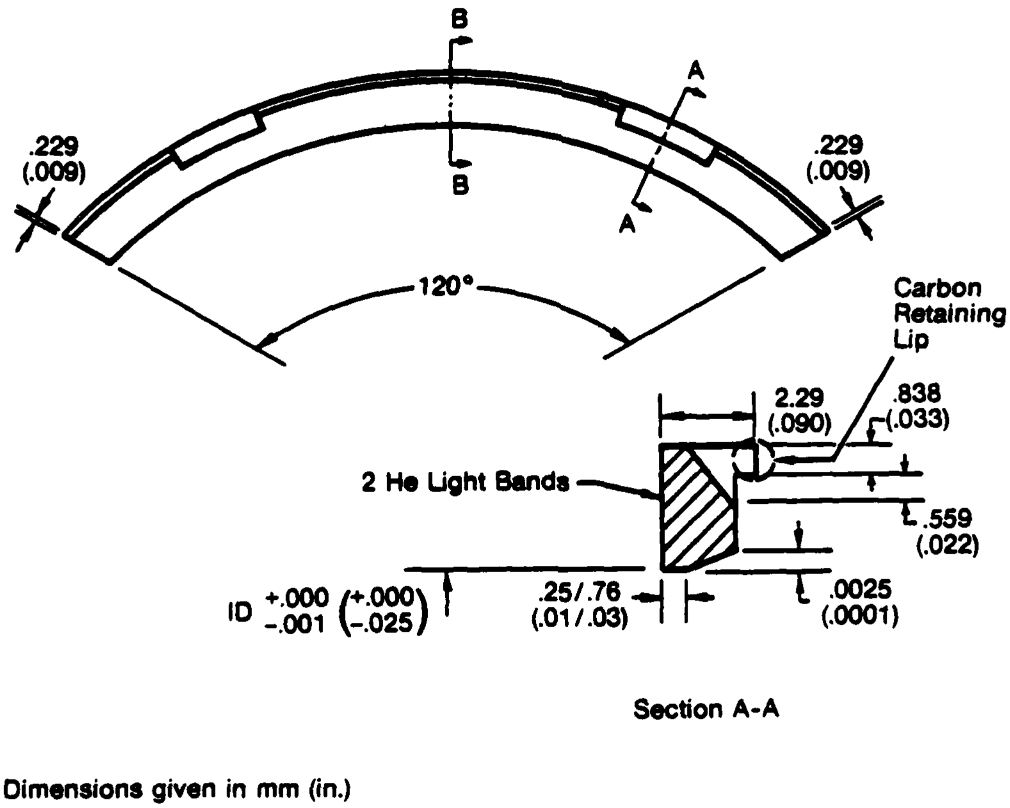

Figure 2. Typical Seal Segment.

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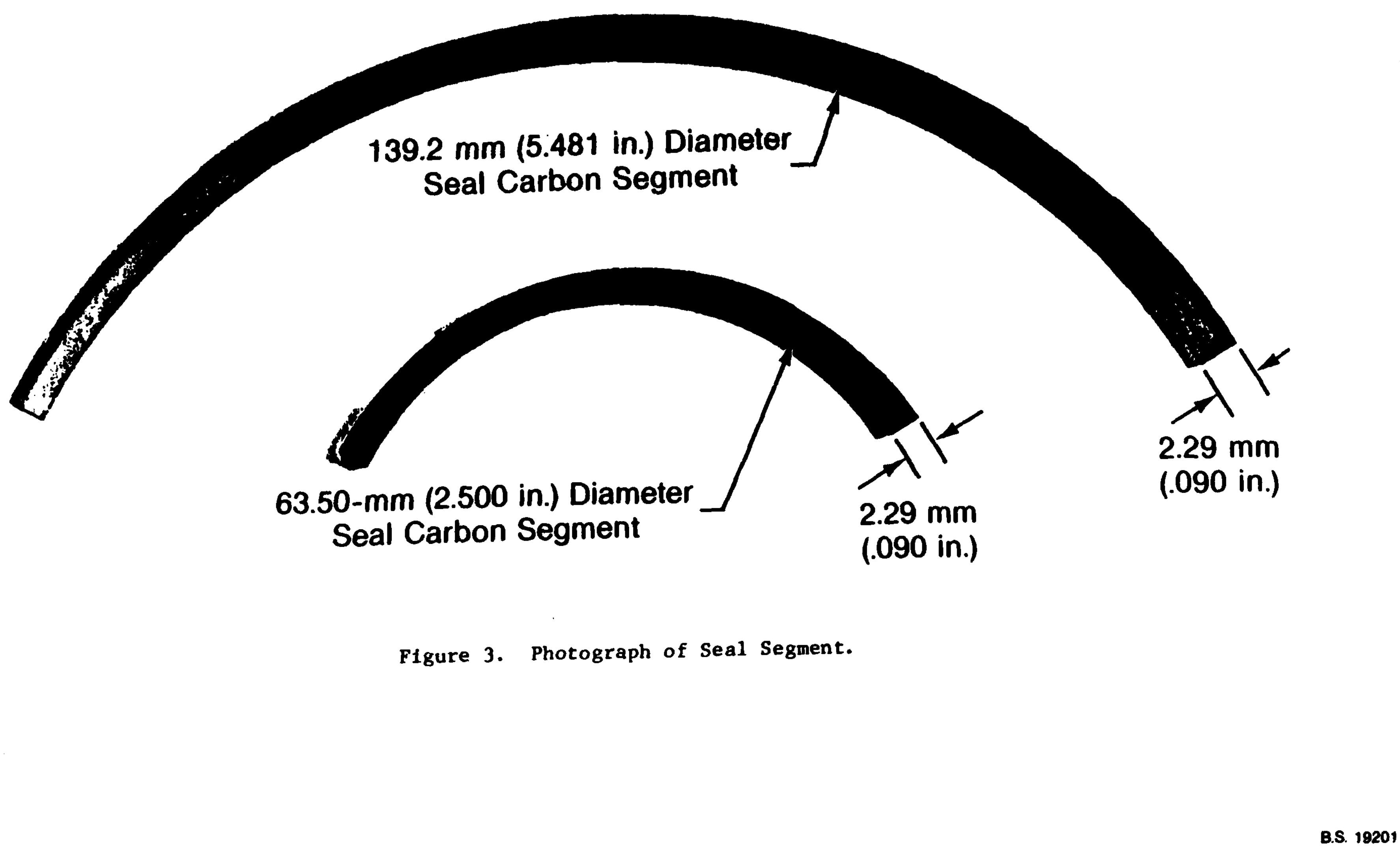


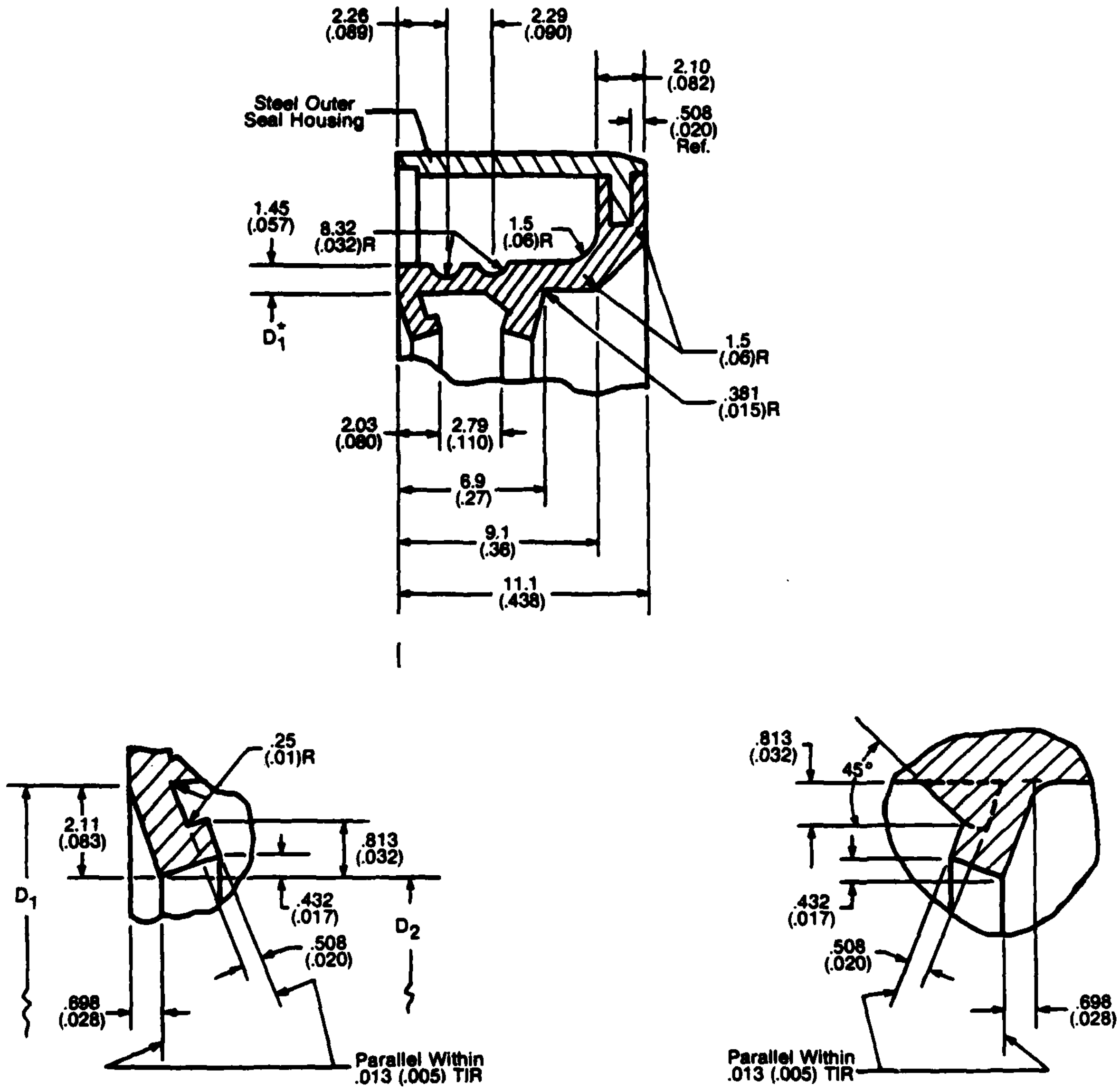
Figure 3. Photograph of Seal Segment.

This conclusion is based on the existence of large internal forces generated as the very high viscosity fluorocarbon is forced through the mold at molding pressures reaching 50,000 psi. Therefore, the recommended alternate approach was to mold precision pockets for the carbon segments in the elastomer-molded seal structure, including the antirotation stops. A simple assembly fixture could then be used to insert the carbon segments into the precision molded pockets. The additional requirement that the carbon not adhere to the rubber after molding was easily met by this technique.

Figure 4 shows a cross section of the final molded shape and its required dimensions. In order to meet these dimensional requirements, the effects of elastomer shrinkage during the molding and post-cure cycle had to be accounted for. For the hybrid elastomer seal, the shrinkage value of the elastomer is not a constant; rather, it is some nonlinear function of the axial distance of the molded section from its attachment point on the outer seal housing, its nominal diameter, and its radial thickness.

A mold that would provide geometrically acceptable parts while accounting for the fluorocarbon shrinkage proved very difficult to produce and required several trial-and-error builds until a mold meeting this requirement was produced. No drawings exist for the mold, which remains the property of the molder; reordering would be by drawing number of the component required. The final mold design, capable of producing production lot quantities of molded parts, consisted of a single-cavity multipart injection mold, as shown in Figure 5. Figure 6 shows a cross section of the final molded configuration; excluded from the photo are the antirotation lugs. The natural variability of the shrink rate for molded fluorocarbon precludes maintaining the precise tolerances included on the piece parts drawings. Tolerances closer than ±0.25 mm (0.01 in.) generally cannot be maintained. The normal variations which occurred in the molded parts examined under this program were easily accommodated by the flexibility of the elastomer.

A problem typical to the molding process for fluorocarbon elastomers developed during the time that the elastomer part was removed from the mold prior to the post-cure cycle. Nearly 40% of the molded parts suffered from hot-tearing during removal. No means were devised to prevent this loss, which was due to the



Antirotation Lug

	Small Seal mm (in.)	Large Seal mm (in.)
D_1	69.72 (2.746)	147.2 (5.796)
D_2	65.50 (2.580)	141.2 (5.560)

Figure 4. Molded Elastomer Cross Section.

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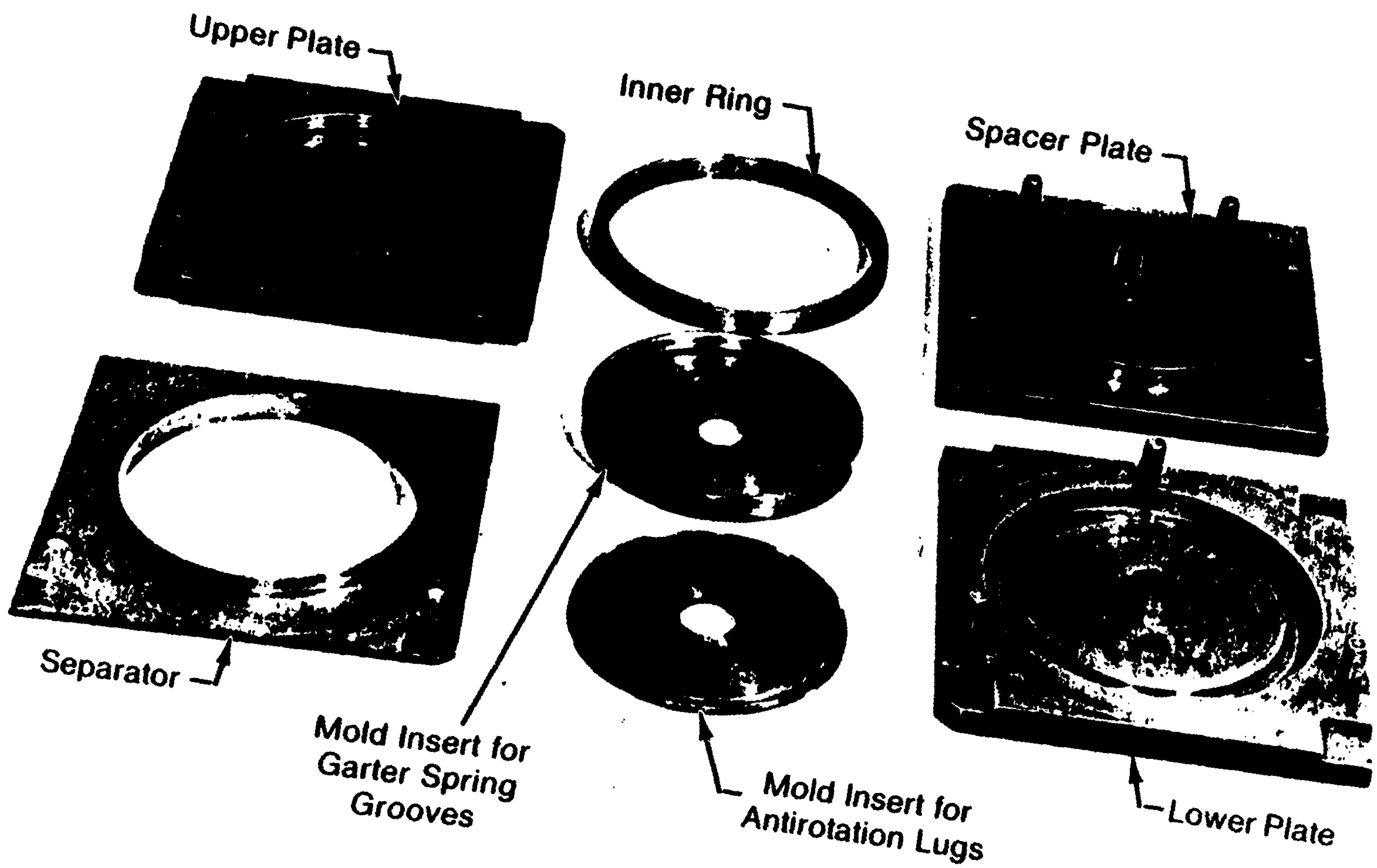

Figure 5. Components for Single-Cavity Injection Mold.

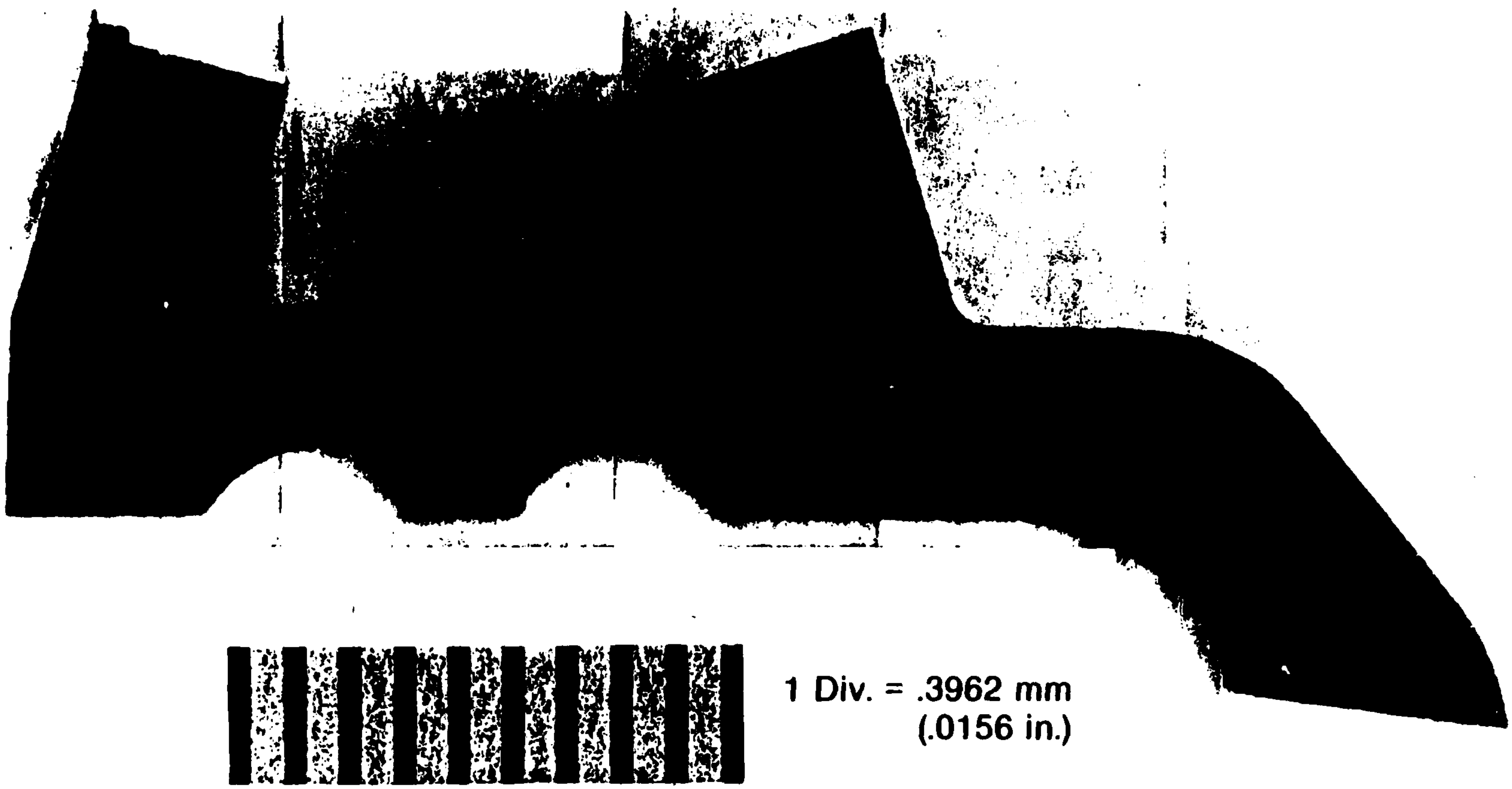

Figure 6. Elastomer Cross Section.

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intricate interior elastomer cavities required by the seal design and the natural tendency for fluorocarbons to exhibit this behavior.

3.3 Garter Springs

The hybrid seal's garter springs were made from AISI type 304 stainless steel wire 0.380 mm (0.015 in.) in diameter. The springs were close wound to a 1.570 mm (0.062 in.) nominal outside diameter. A four-turn nib was placed on one end of each 508 mm (20.0 in.) long spring. Springs were cut to length at assembly to ensure proper spring tension.

3.4 Component Inspection

Each seal component was inspected prior to assembly to establish conformity to drawings and specifications. Normal inspection-room metrology techniques were used and no special gages or fixturing were employed.

Agreement between requirements and components was found to be good, with the exception of one area: the inability to hold the precise tolerances specified for the molded elastomer. Reasons for this exception were covered in Section 3.2 of this report.

3.5 Seal Assembly

Specialized fixtures were developed to assure proper assembly of the hybrid seal. Figure 7 illustrates schematically a typical carbon ring insertion fixture design. Detailed parts drawings for the assembly tooling are included in the back of the report; a complete listing is included in Appendix A. The fixture includes a main body to which is keyed a removable lower seal ring indexer. The indexer contains three equally spaced separators for accurately positioning three adjacent carbon ring segments. After all six carbon ring segments are installed in the fixture, the seal ring clamp, also keyed to the main body, is positioned to retain the carbon ring. The upper seal ring indexer is then installed. The upper indexer, keyed to the ring clamp, also contains three equally spaced separators to orient properly the second group of three carbon ring segments. Figure 8 is a photograph of the actual fixture.

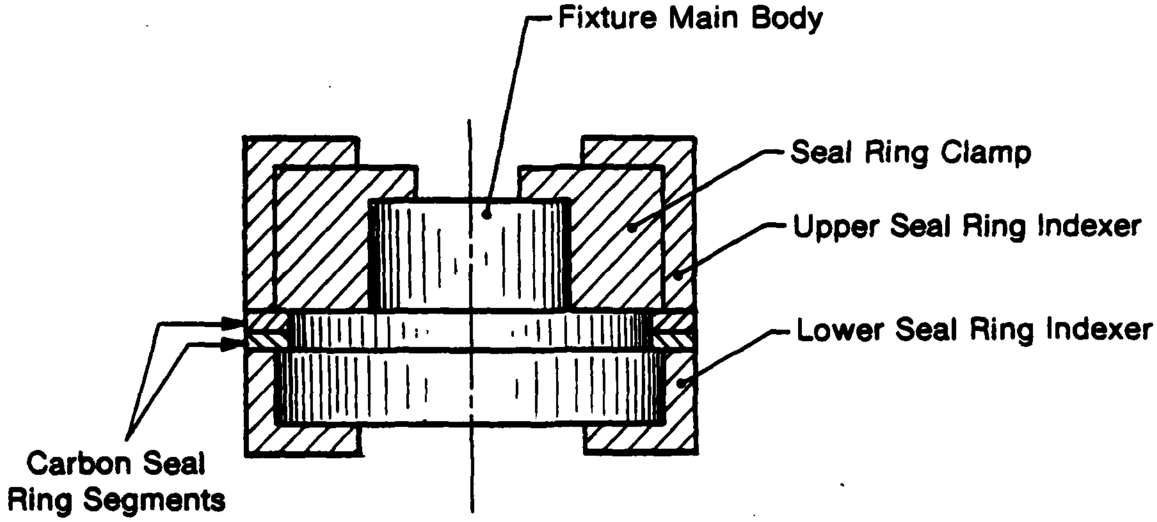

Figure 7. Schematic of Carbon Ring Installation Fixture.

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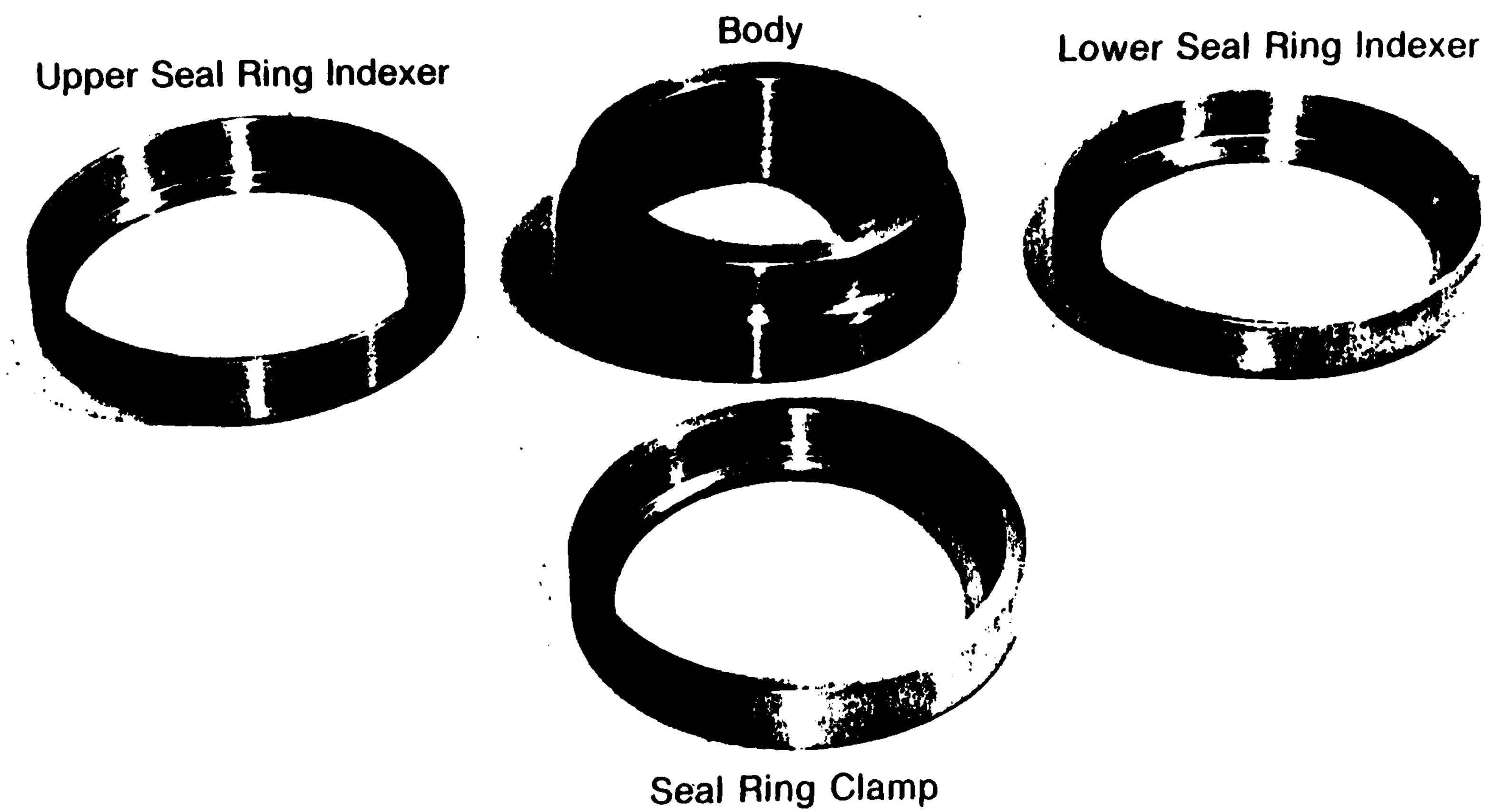

Figure 8. Photograph of Carbon Ring Installation Fixture.

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When assembling a seal, the seal's molded component, pressure side down, is lowered over the fixture until its seal ring retention lip passes over the carbon rings. The fixture is then inverted, the lower indexer removed, and the retention lip eased over the carbons. The fixture is inverted again, and with some slight up-and-down motion of the elastomer, the upper indexer is removed. When the carbons are fully captured by the elastomer, the ring clamp is disassembled and the seal removed.

At assembly, garter springs are cut to proper length. The proper garter spring length is established by the following procedure:

1. From the detailed parts drawing for the molded elastomer dimensions, the nominal garter spring length is calculated to be 471 mm (18.54 in.) for the large seal and 227 mm (8.93 in.) for the small seal. The appropriate number of springs are cut to this length.

2. When the nib end of each garter spring is screwed, in turn, into a suitable receptacle, the spring is stretched with the appropriate tension load of 8.90 N (2.0 lb) for the large seal and 7.78 N (1.75 lb) for the small seal. In this stretched condition, the spring is cut to the length specified in Step 1.

The springs are installed using the fixture shown in Figure 9. With carbon rings installed, the seal is placed on the fixture; the garter springs are then rolled over the fixture and into their proper positions in the seal.

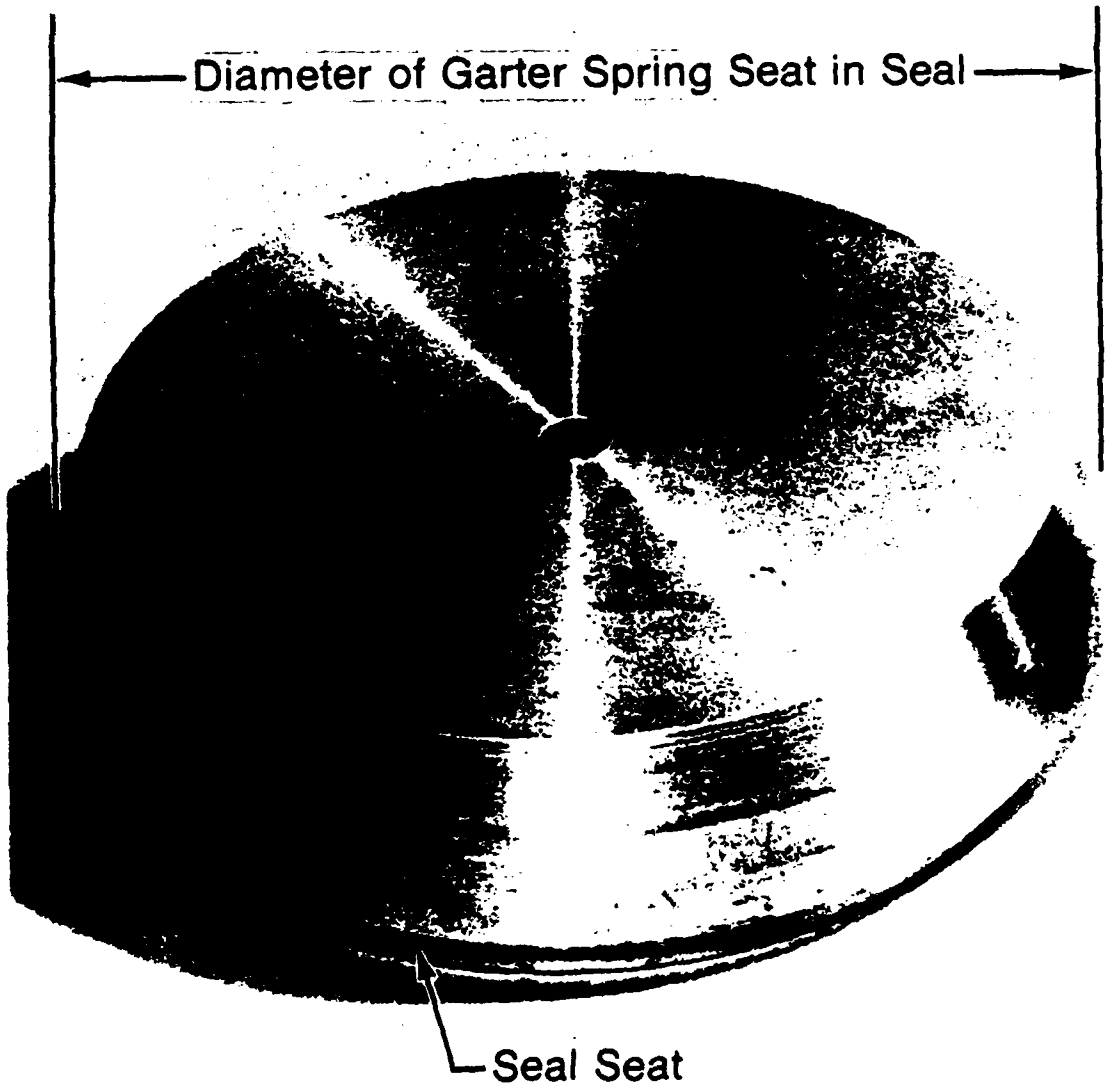

Figure 9. *Garter Spring Insertion Tool.*

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4.0 SEAL TESTING

4.1 Seal Testing Program

The seal test program, as specified by the Statement of Work and later modified, included the following tasks:

- Task 1 - Static Tests on 63.50 mm (2.500 in.) (Small) and 139.2 mm (5.481 in.) (Large) Diameter Seals. Ten seals of each size were checked for:

  Light tightness
  Lip contact percentage
  Air leakage measurement
  Seal lip contact force*.

  The above tests were conducted with the following garter spring tensions:

  Small seal: 7.78 N (1.75 lb) per spring
  Large seal: 8.90 N (2.00 lb) per spring.

- Task 2 - Dynamic Tests on the Large-Diameter Seals. Dynamic testing of nine seals was performed according to the test matrix shown on Table 2. The lubricant for all tests was type II turbine oil (MIL-L-23699). Six tests were conducted using three lubricant jets impinging directly on the seal carbons. Three tests employed a single jet impinging on the runner.

4.1.1 Seal Inspection and Seal Rework

The test runs were interrupted to inspect the seals whenever the test parameters indicated unusual seal operation. When inspection indicated that the test could be satisfactorily continued after seal rework, the rework was performed and the test continued. When a seal failed or its performance was unsatisfactory, an

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*Not specified in SOW but included for completeness on the large seal.

TABLE 2. DYNAMIC TESTING: TEST MATRIX

Test No.	Velocity m/s (ft/min)	Seal Pressure MPa (lb/in.^{2})	Runner Runout mm (in.)	Oil Out °C (°F)	Time (hr)
1	50.8 (10,000) @7500 rpm	0 (0)			
2	"	6.9×10^{-3} (1)	0.025 (0.001)	65.6 (150)	3
3	"	1.4×10^{-2} (2)			
4	76.2 (15,000) @10,500 rpm	0 (0)			
5	"	6.9×10^{-3} (1)	0.025 (0.001)	65.6 (150)	3
6	"	1.4×10^{-2} (2)			
7	101.6 (20,000) @14,000 rpm	0 (0)			
8	"	6.9×10^{-3} (1)	0.025 (0.001)	65.6 (150)	3
9	"	1.4×10^{-2} (2)			

analysis was made to determine the cause of failure. Seal rework, where possible, was performed and the seal in question was retested.

4.1.2 Data Collection

Test data were collected as specified, including pretest data, recorded test data, and post-test data. Prior to the start of seal testing, each seal to be tested was measured for the following:

- Rotor diameter
- Rotor roundness
- Carbon thickness
- Spring radial load
- Shaft taper.

The following parameters were measured and recorded during all test runs:

- Seal lubricant leakage rate (by collection means)
- Sealed pressure
- Rig speed
- Temperature of lubricant (in and out)
- Torque
- Lubricant flow rate
- Shaft dynamic runout near seal location.

All items measured at the pretest inspection were re-examined at the completion of each test. A careful visual examination was made of each seal, and photographs of normal as well as unusual post-test conditions were taken.

4.2 Seal Test Apparatus

4.2.1 Seal Contact Pressure Tester

A measure of the clamping force that a lip seal imparts to the shaft against which it is working is related to garter spring tension and may be an indication of probable wear or leakage rates. To determine this force, a simple radial force gage was constructed; see Figure 10. A detailed part drawing is listed in Appendix A and is included in the pocket at the end of the report. The primary element of this gage is the flexure arm which is calibrated using a dial indicator and a strain gage bridge for measuring force. To use the fixture, the adjusting screw is retracted, permitting the fixture to be collapsed for installation of a lip seal on its appropriate gaging diameter. The adjusting screw is then turned until the gaging diameter expands to the correct shaft diameters, as indicated on the dial indicator. The force required to stretch the seal to this position is read on the output of the strain gages. Subsequent checks of this force can be used as an effective measure of seal usefulness since a falloff of force is representative of seal wear. With sufficient test data, a base-line force level can be established. Figure 11 shows the force gage calibration curve for the two seal sizes examined. Sufficient test samples (only eight large seals were tested) were not available, however, to establish a quality acceptance criteria for the large or the small seals for this test.

4.2.2 Static Tester

The static seal tester, set up for measuring the large-diameter seal, is shown in Figure 12. The tester consists of a simulated seal runner mounted in a light box. A circular fluorescent light bulb mounted in the light box provides the illumination source. An O-ring sealing adapter provides both a radial seal and cover seal for isolating the test seal during leakage tests. With the cover removed, the hybrid seal can be checked for light tightness and qualitatively measured for percentage of contact by blueing procedures; with the cover installed, pressurization of the seal establishes its propensity for air leakage. Detailed drawings of the static tester and associated parts for both the large and small seal can be found in the pocket at the end of the report; the drawings are also listed in Appendix A.

4.2.3 Dynamic Tester

Figure 13 shows a cross section of the seal test rig and Figure 14 shows a photograph of the installed rig. The salient features of the tester can be described

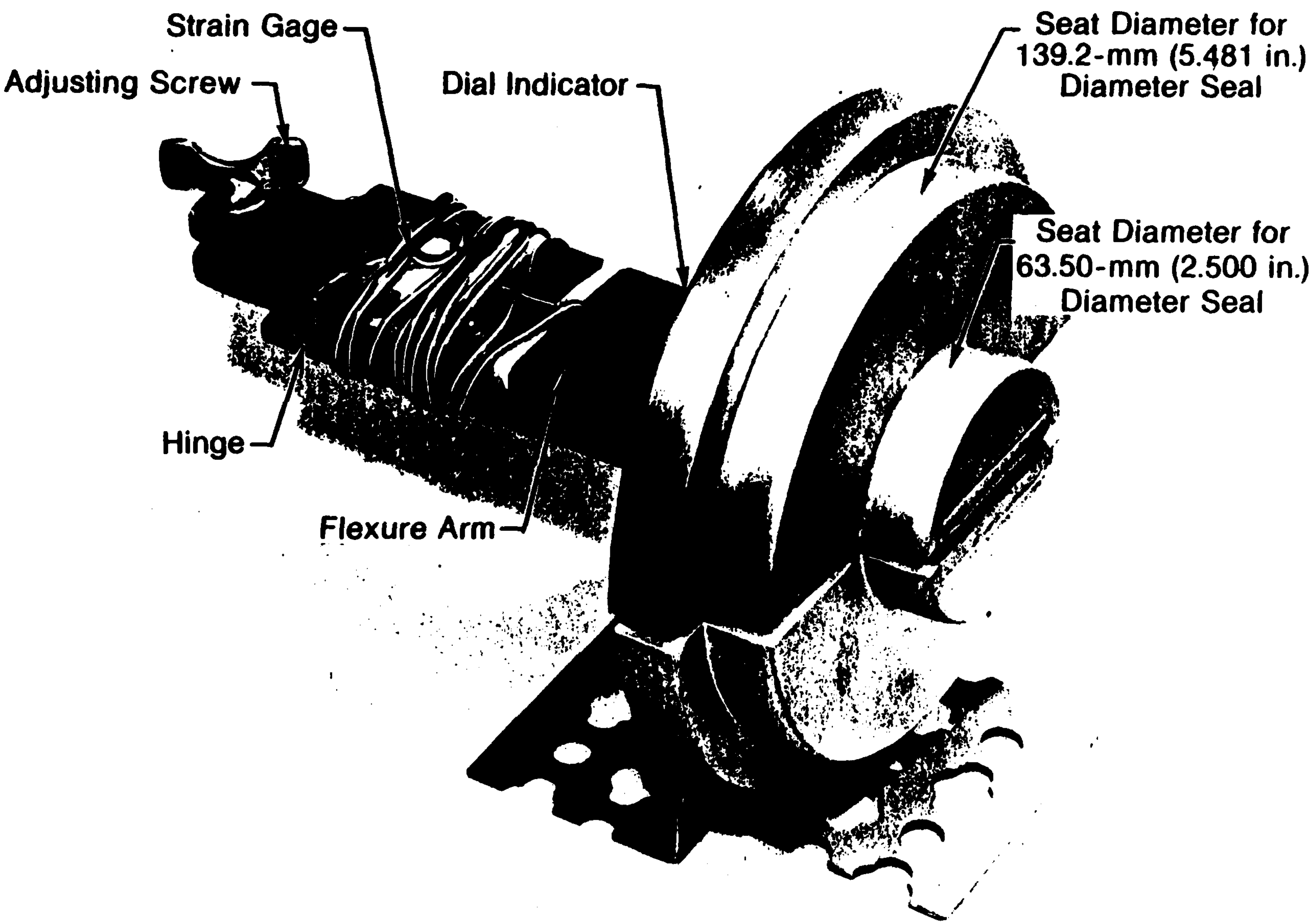

Figure 10. Radial Force Gage.

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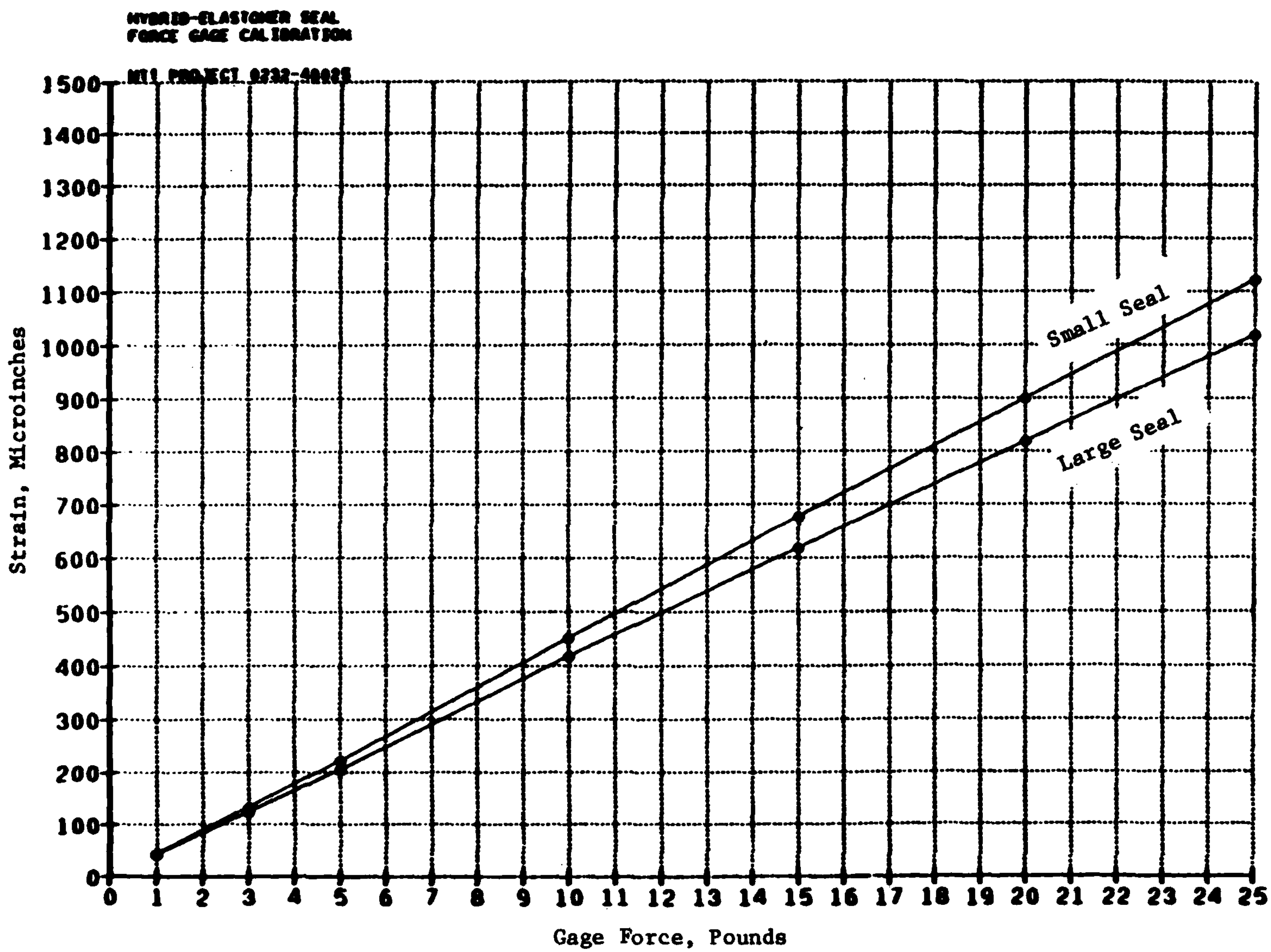

Figure 11. Force Gage Calibration Curve.

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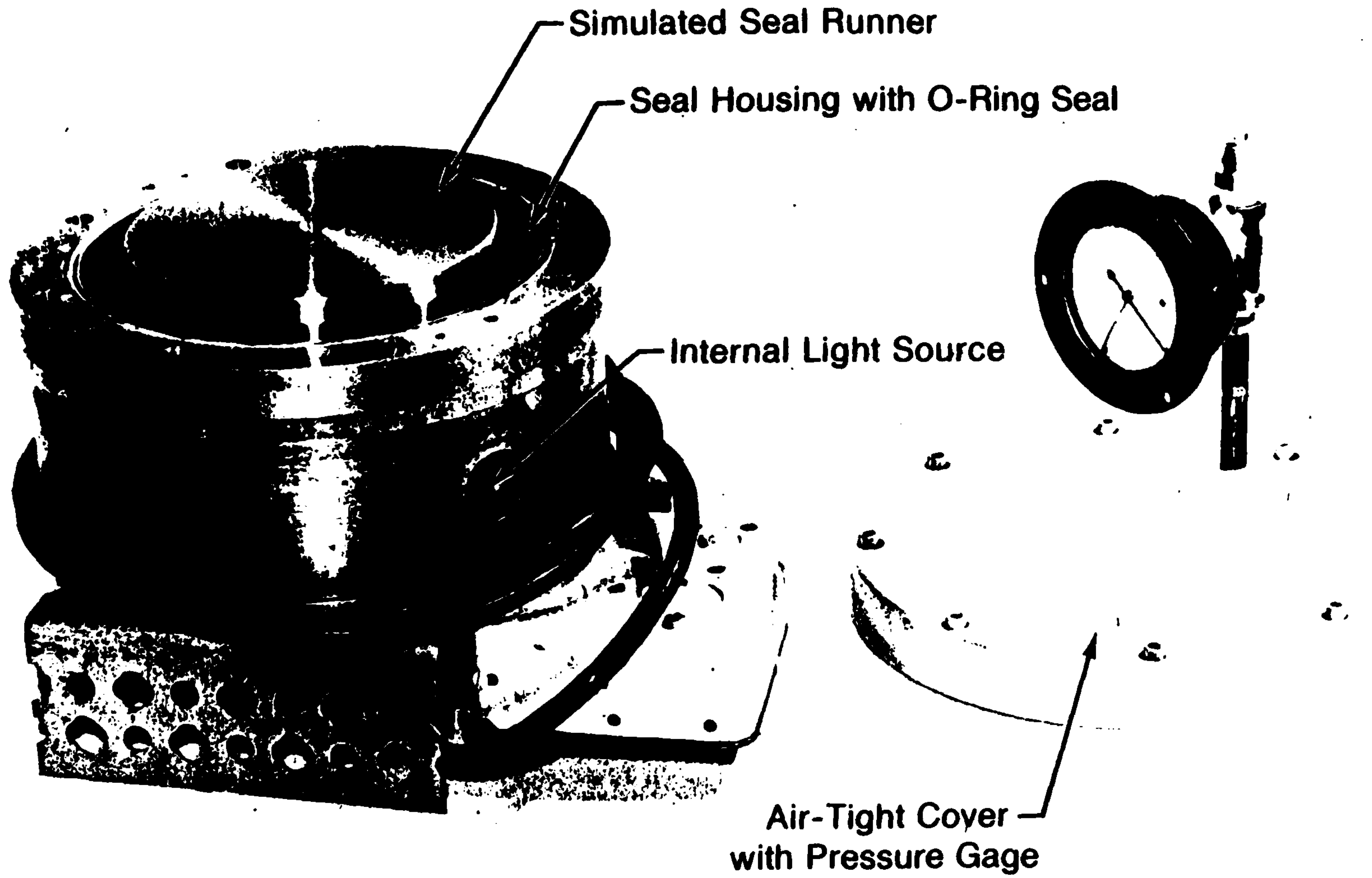

Figure 12. Static Seal Tester.

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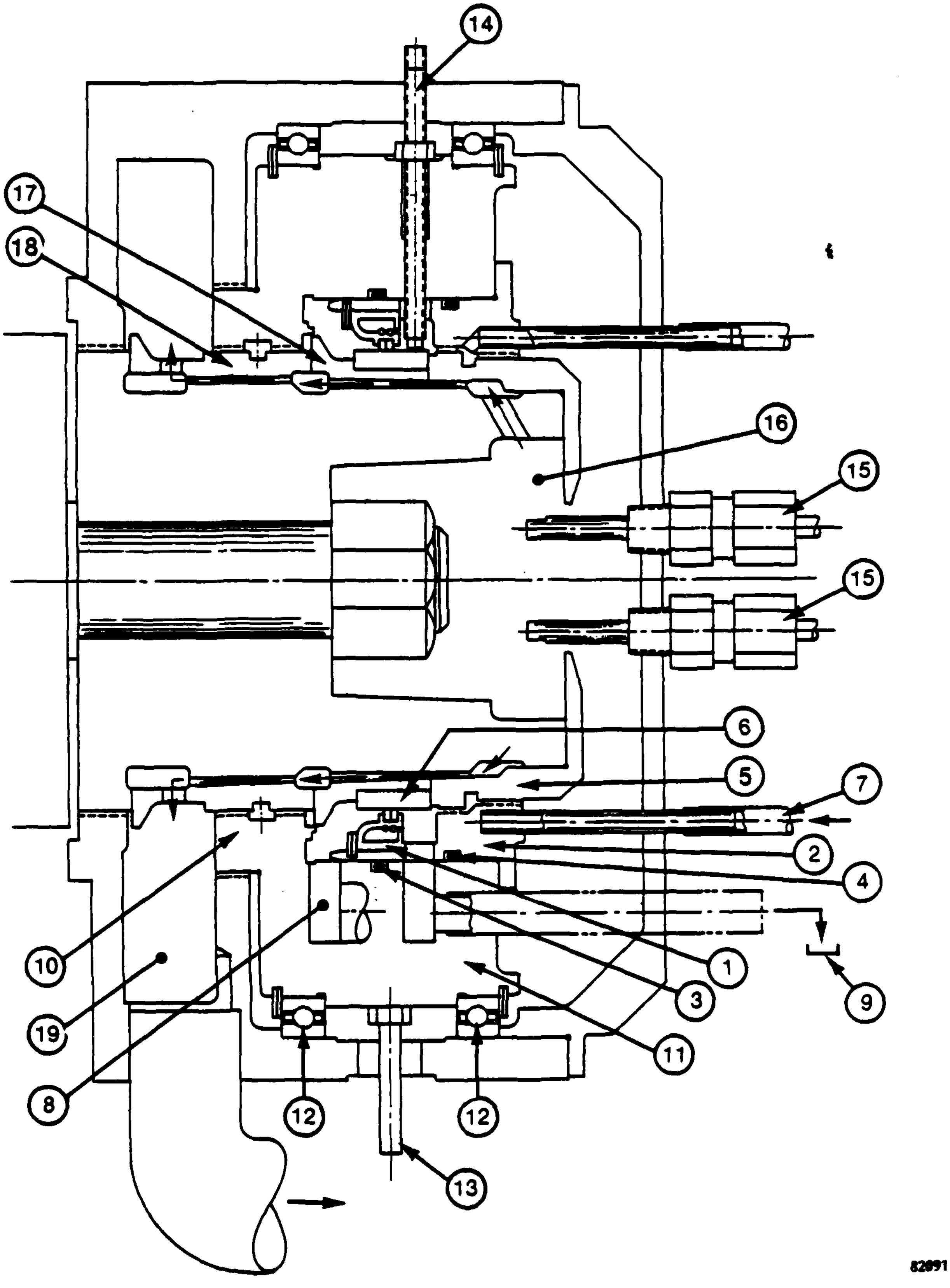

Figure 13. Seal Test Rig Cross Section.

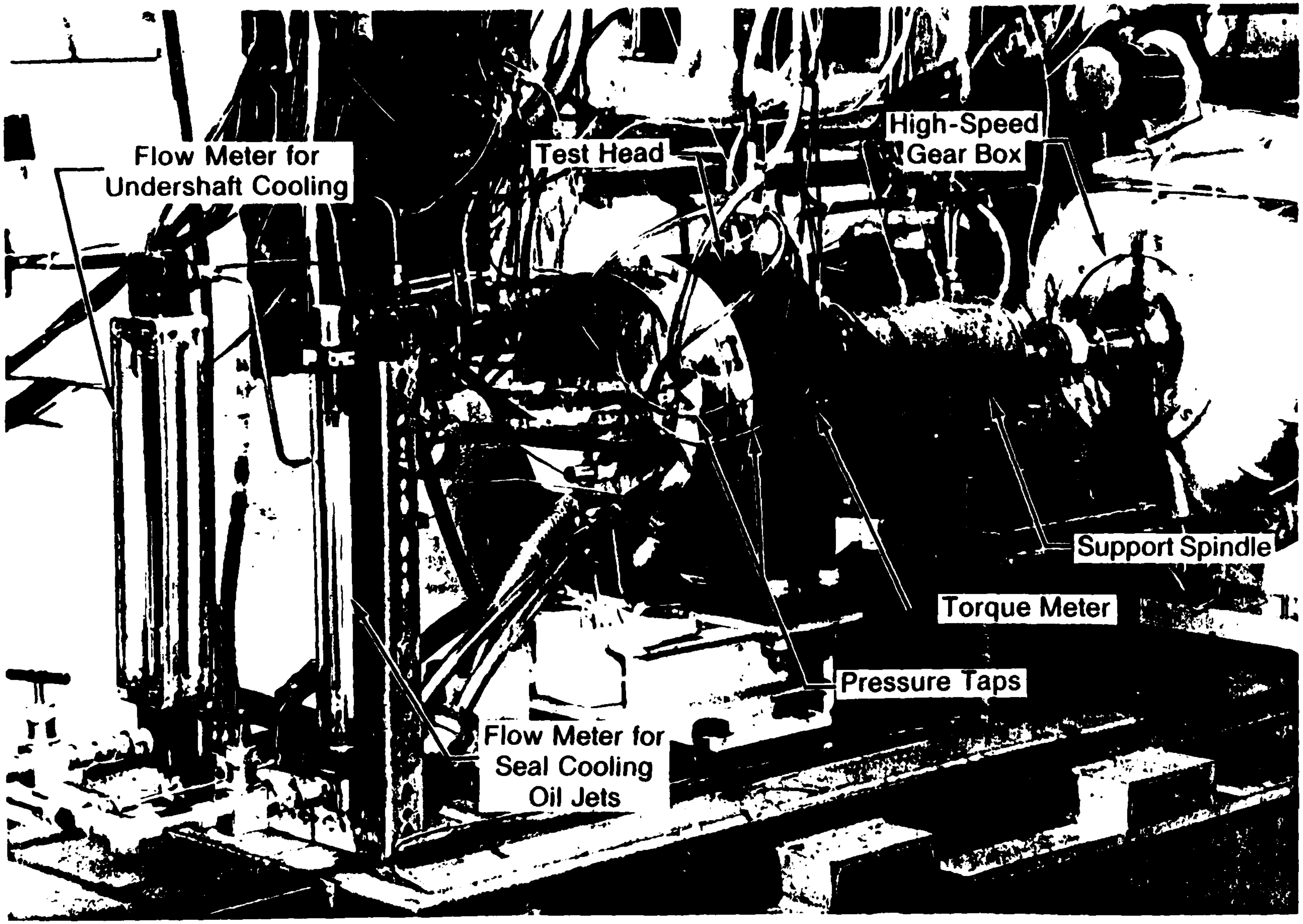

Figure 14. Installed Seal Test Rig.

B.S. 19204

as follows. The test seal (1)* is mounted in a special carrier (2) with O-rings (3) and (4) and the buffered labyrinth seals (5) that preclude oil leakage around the seal. A removable seal runner (6) is also provided.

Test oil, specified as MIL-L-23699, is injected into the seal inlet cavity via oil supply nozzles (7). For six tests, three impinging jets were employed supplying a total of 378 cc/min (1 gpm). For three tests, only one jet passing oil at a rate of 125 cc/min (0.33 gpm) was employed, with the jet impinging on the runner rather than the seal itself. In addition, each of the last three seals to be evaluated were tested for only 2 hours at each test point, for a total of 18 test hours.

Any oil leaking past the seal is collected in the oil discharge cavity (8) which directs the oil to the collection container (9). A second buffered labyrinth seal (10) prevents the interchange of leakage oil with other oil present in the test head. The seal carrier is securely installed into a carrier housing (11) which is suspended from the tester housing by two ball bearings (12). This arrangement permits sufficent rotational freedom to the carrier housing to allow the addition of a torque measuring restraint (13). Two eddy-current position sensors (14) are mounted in the carrier housing to monitor seal runner excursions during testing.

Under-seal cooling oil is provided by two oil feeders (15) which direct oil at a rate of 378 cc/min (1 gpm) into an internal collection cavity (16). From this cavity, oil is centrifugally pumped through special channels under the seal runner mount (17) and under the rear labyrinth seal runner (18) into the cooling oil drain cavity (19).

The entire test head is mounted on a high-speed precision ball bearing spindle which is driven by a 74.6 kW (100 hp) variable-speed drive. Pressure gages are connected to both the seal inlet and discharge cavities to monitor both level and ΔP.

*Circled numbers identify rig components on Figure 13.

5.0 TEST RESULTS

5.1 Test on the Small-Diameter Seal

Each of the eleven small-diameter seals sent to the Government were subjected to static testing prior to shipment. Inspection reports covering the static testing of these seals can be found in Appendix B. Dimensional and visual inspection of these seals showed little or no difference in their physical characteristics. Contact percentage showed only small differences concentrated around the 80% level. However, a large variation occurred in the air leakage test results. Air leakage for some seal assemblies exceeded 150 cc/hr. The discrepancy can, for the most part, be attributed to local irregularities in the topography of the carbon insert's runner contact area and to the fact that the tolerance of the actual axial length of the contact area is such that its length can vary by three-to-one, giving rise to the possibility of a three-to-one flow variation, all other parameters being equal. The small-diameter seals were not subjected to dynamic testing prior to delivery to the Government.

The final dimensions (see Figure 2) specified by the Government for the carbon rings in the shaft-riding area precluded any possibility of lapping the seal bore after assembly, since the lapping would rapidly remove any trace of the desired axial taper. As a result of the inability to provide final bore lapping, any tool marks left on the inner diameter of the carbon rings remained in the assembled seals. These bands showed up as parallel heavy contact lines after blueing.

5.2 Test on the Large-Diameter Seal

5.2.1 Static Tests

Each of nine large-diameter seals was subjected to static testing prior to undergoing dynamic tests. Inspection reports covering the static testing of these seals can be found in Appendix C. The large-diameter seals showed static results very similar to those found for the small-diameter seals, that is, fairly uniform readings of contact percentage as measured by blueing techniques with wide variations in air leakage rates unrelated to either the blueing results or dimensional characteristics. Table 3 presents the static test results which also duplicated the results for the small-diameter seals relative to the appearance of the blueing imprints.

The very small land area for seal contact as defined by the carbon segment drawing (Figure 2) precludes any possibility of lapping out the machining marks which are evident on the blueing imprints. In addition to the static tests, force gage readings (Section 4.2.1) were taken for all seals. The results of these tests are shown in Figures 15 through 22 and are summarized in Table 4. It is evident from Figures 15 through 22 that a significant amount of hysteresis is present in the seal assembly.

5.2.2 Dynamic Tests

Each seal tested statically was also tested for dynamic performance. The dynamic testing was targeted to provide leakage rates and torque data and to include wear data at three levels of rubbing velocity and three differential pressures across the seal. All seals were tested against runners which were machined to have a 0.025 mm (0.001 in.) TIR runout. For consistency with existing transmission seal runners, the test runners were fabricated from AISI type 304 series stainless steel.

The wear data, data for seal runner degradation, and the total test time are included in Table 5. Leakage rates and friction torque results are presented in Table 6.

TABLE 3. STATIC TEST RESULTS - LARGE-DIAMETER SEAL

Seal No.	Leakage Air Pressure MPa (lb/in.^{2})	Rate cc/hr	Blueing Contact (%)
8	2.07×10^{-2} (3)	150	50
9	2.92×10^{-2} (4.25)	100	90
10	6.89×10^{-3} (1)	150	85
11	3.45×10^{-2} (5)	120	75
12	1.38×10^{-2} (2)	150	75
13	3.03×10^{-2} (4.4)	70	85
14	1.38×10^{-2} (2)	120	80
16	3.10×10^{-2} (4.5)	110	70
17	1.73×10^{-3} (0.25)	150	80

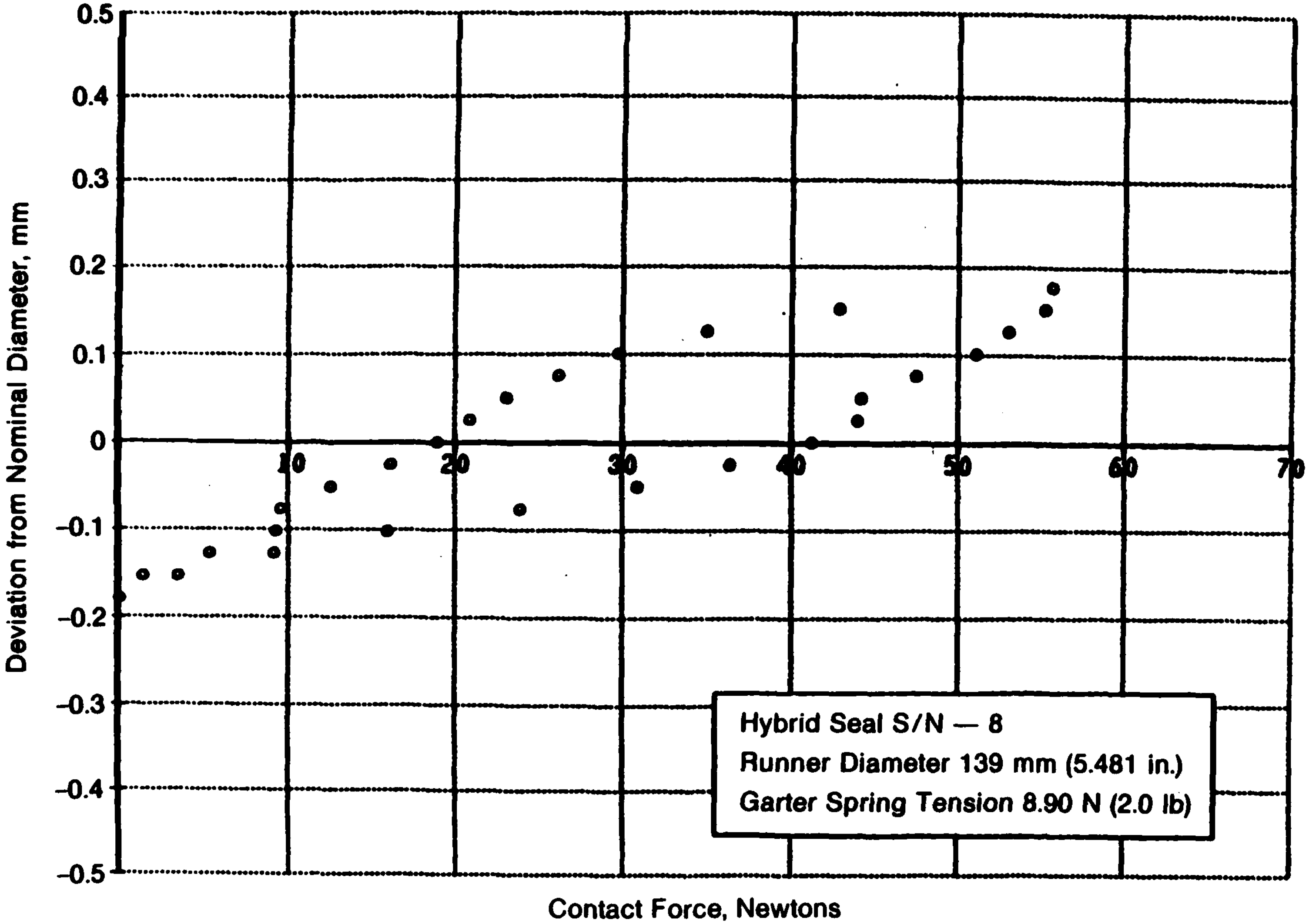

Figure 15. Hybrid Elastomer Seal (No. 8) Runner Contact Force.

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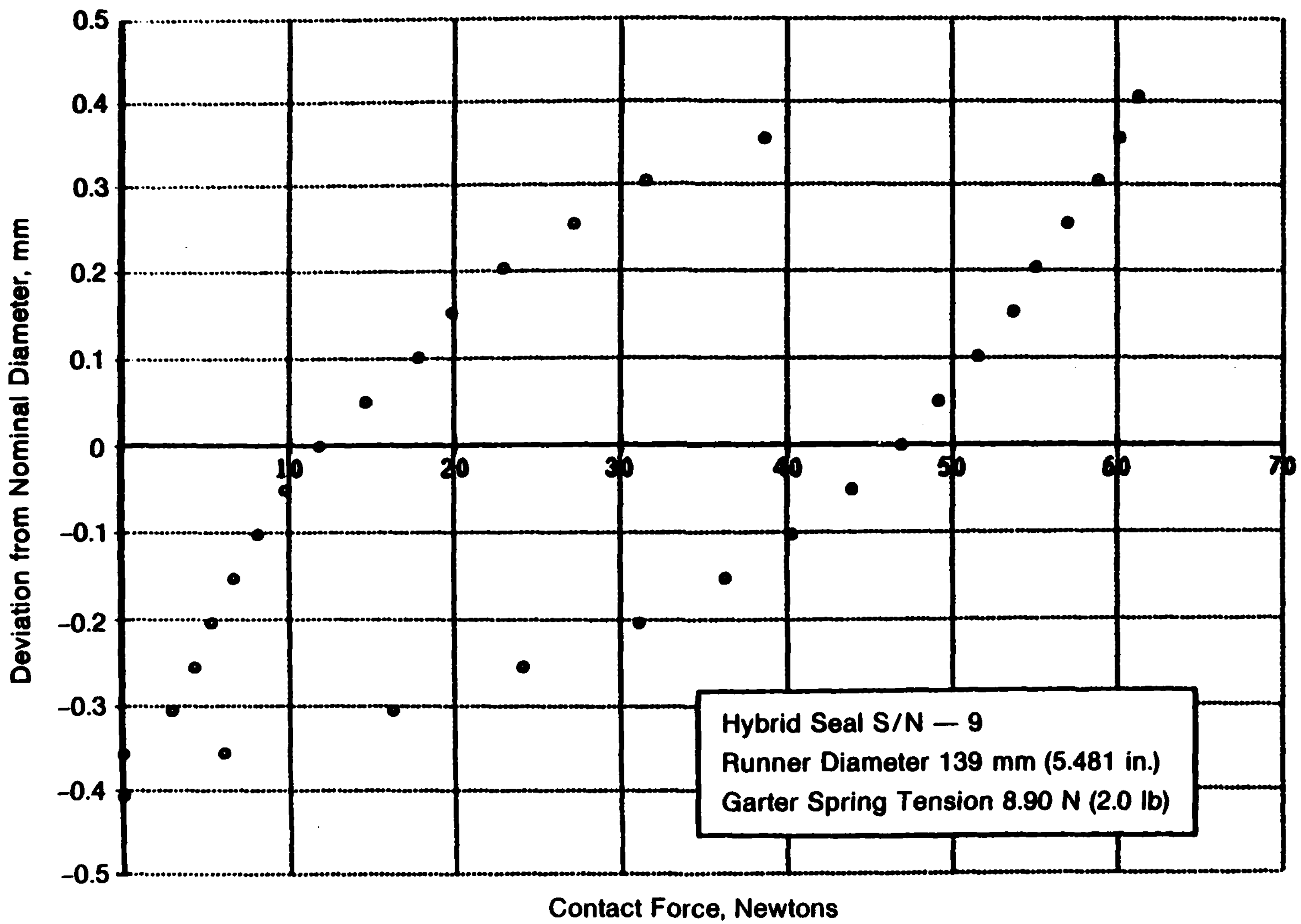

Figure 16. Hybrid Elastomer Seal (No. 9) Runner Contact Force.

83127

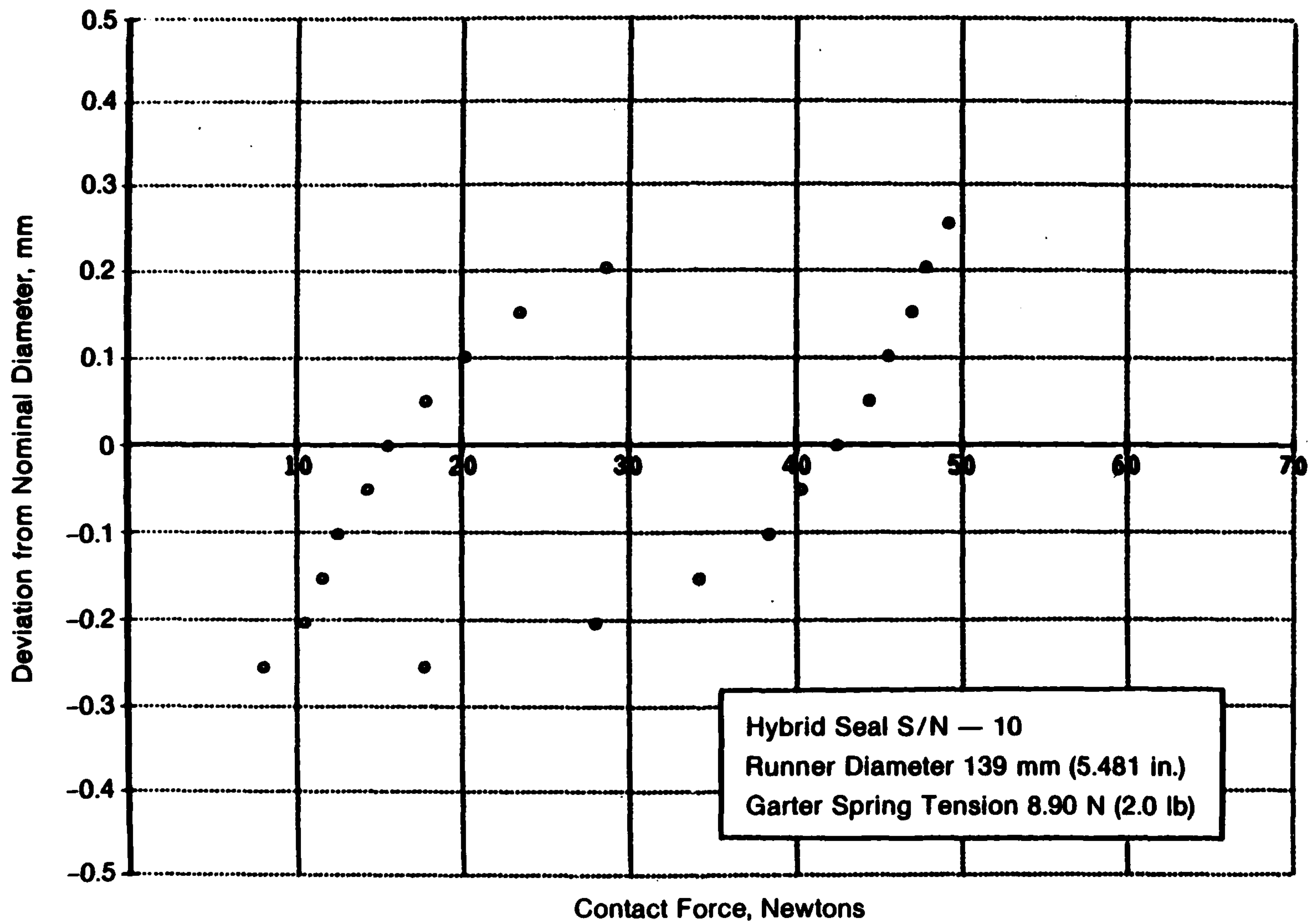

Figure 17. Hybrid Elastomer Seal (No. 10) Runner Contact Force.

83128

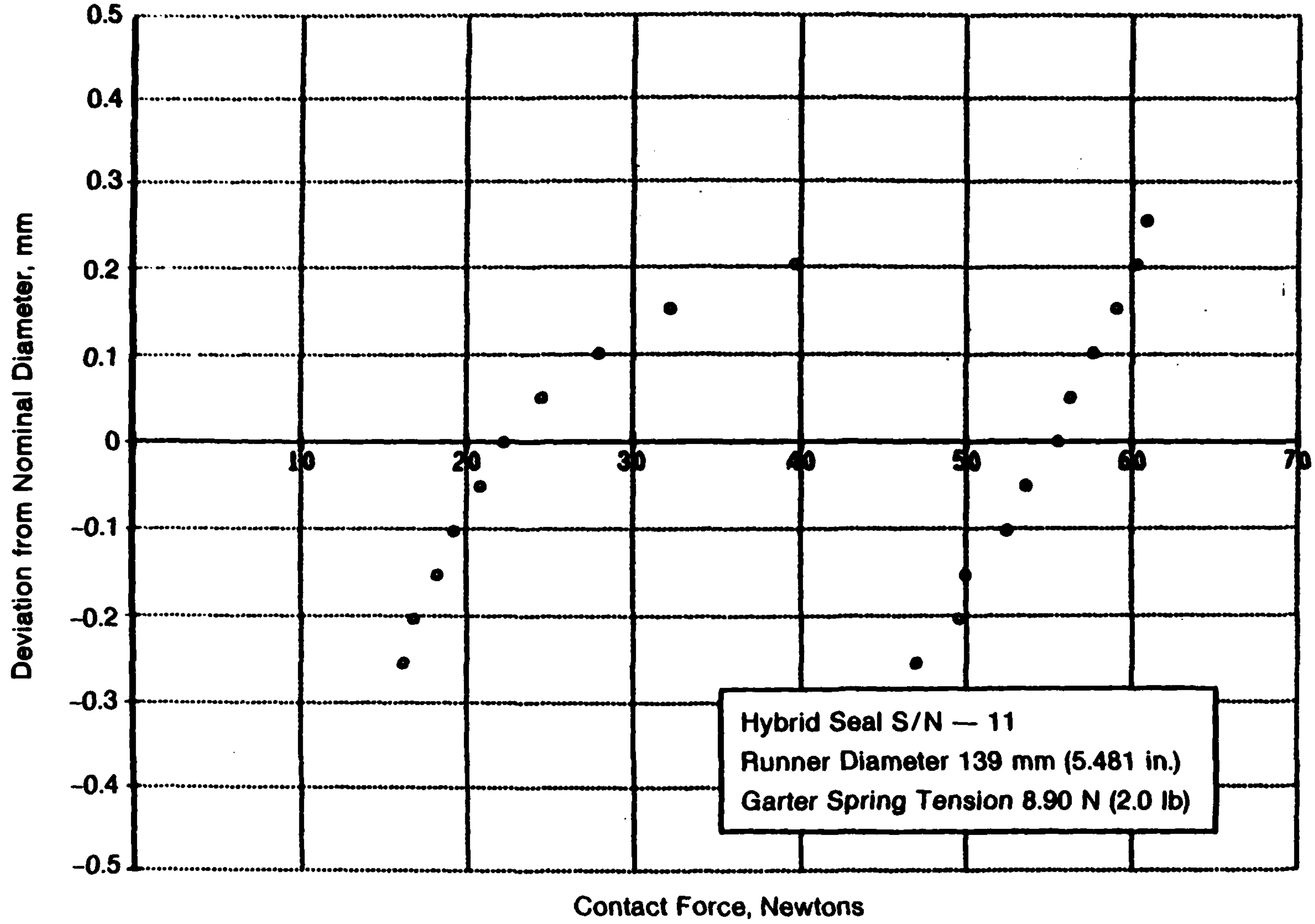

Figure 18. Hybrid Elastomer Seal (No. 11) Runner Contact Force.

83129

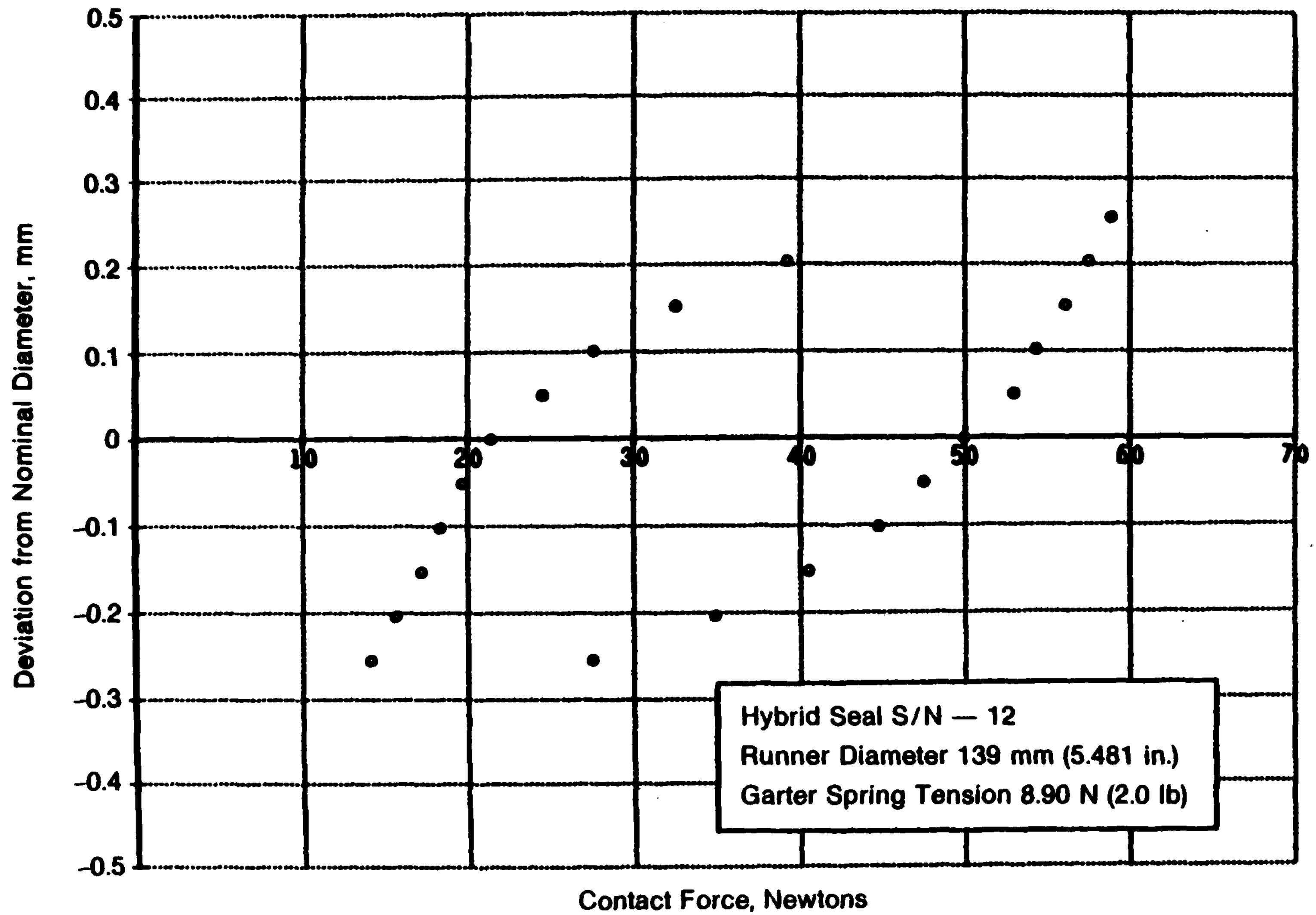

Figure 19. Hybrid Elastomer Seal (No. 12) Runner Contact Force.

83130

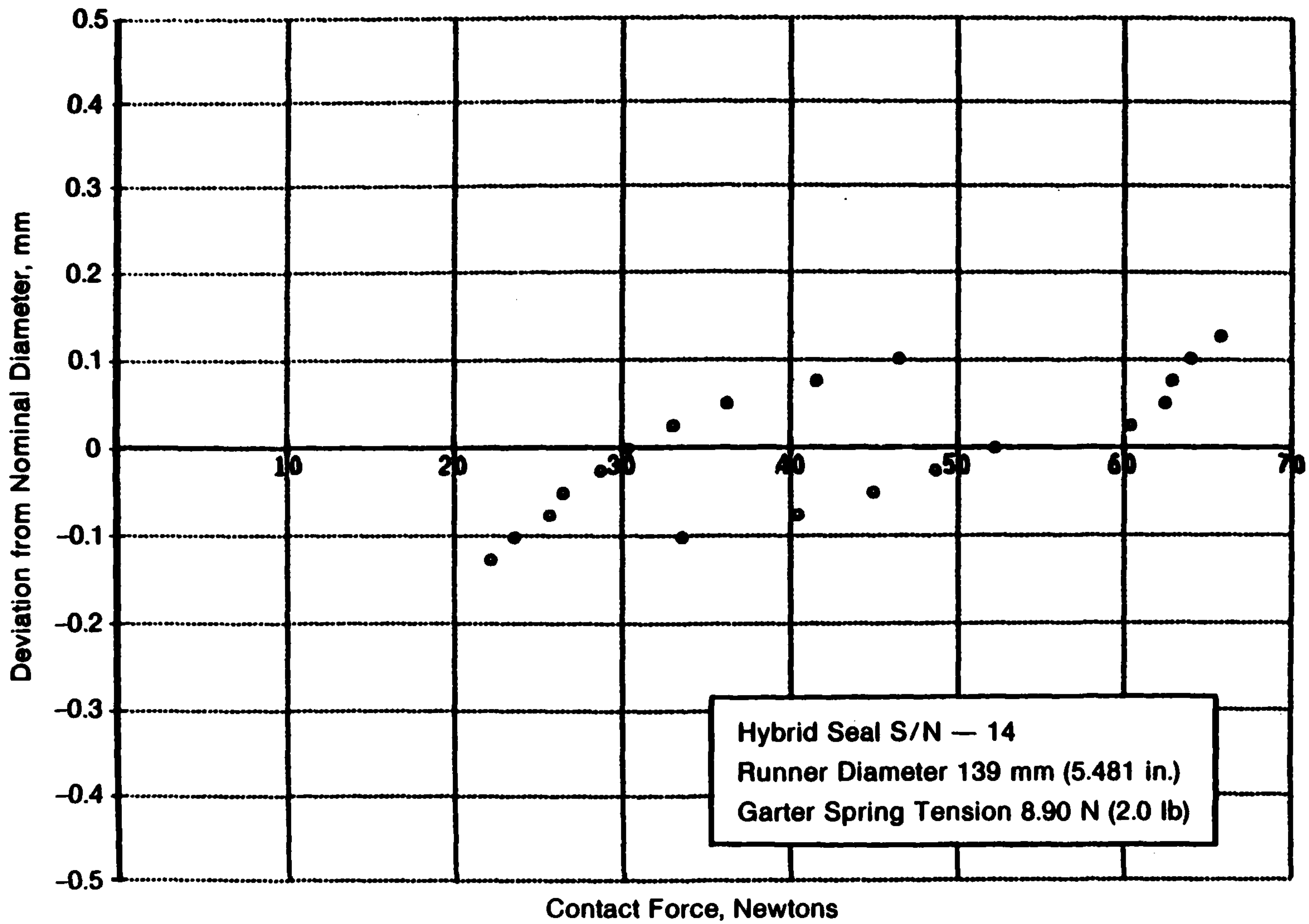

Figure 20. Hybrid Elastomer Seal (No. 14) Runner Contact Force.

83131

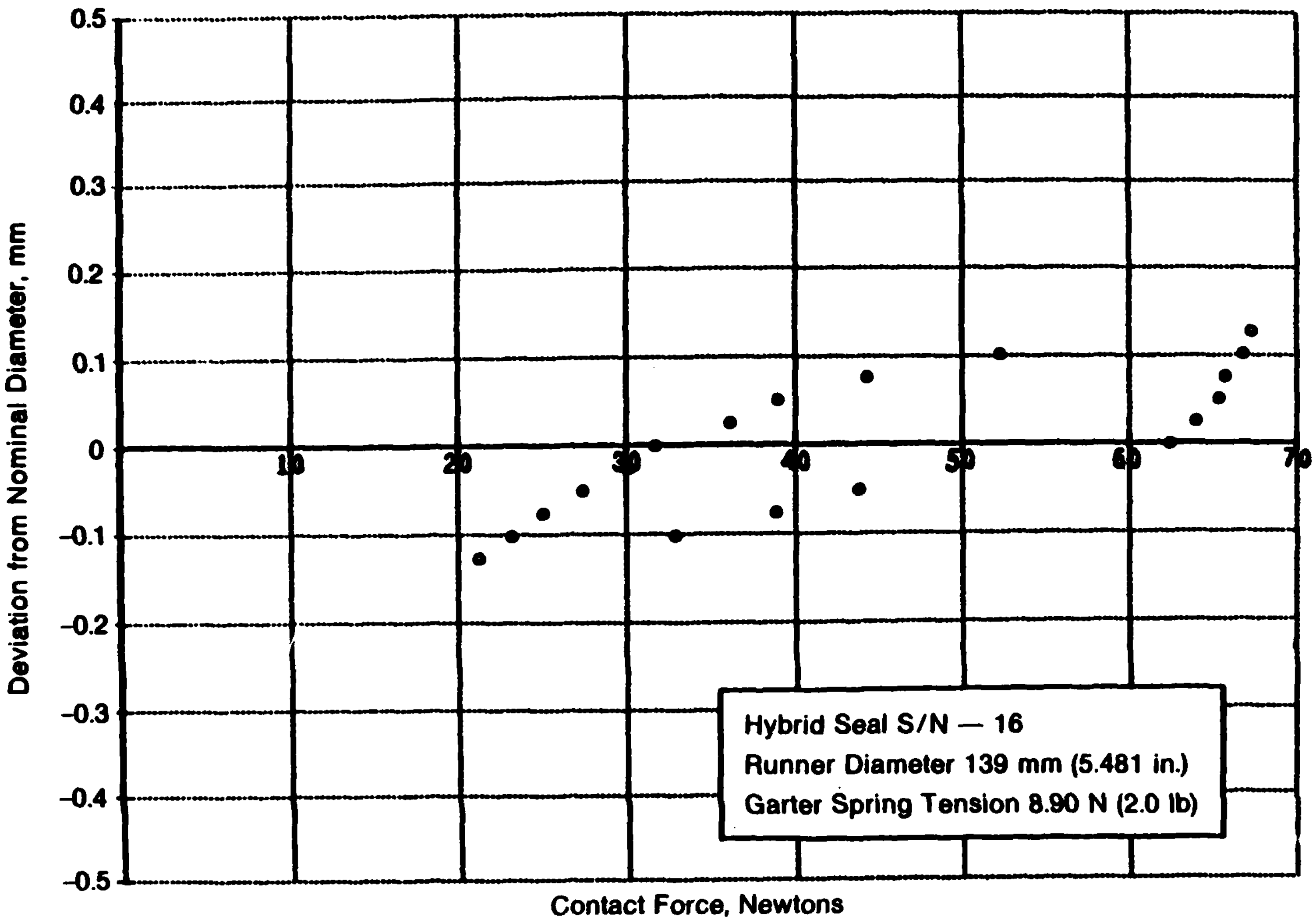

Figure 21. Hybrid Elastomer Seal (No. 16) Runner Contact Force.

83132

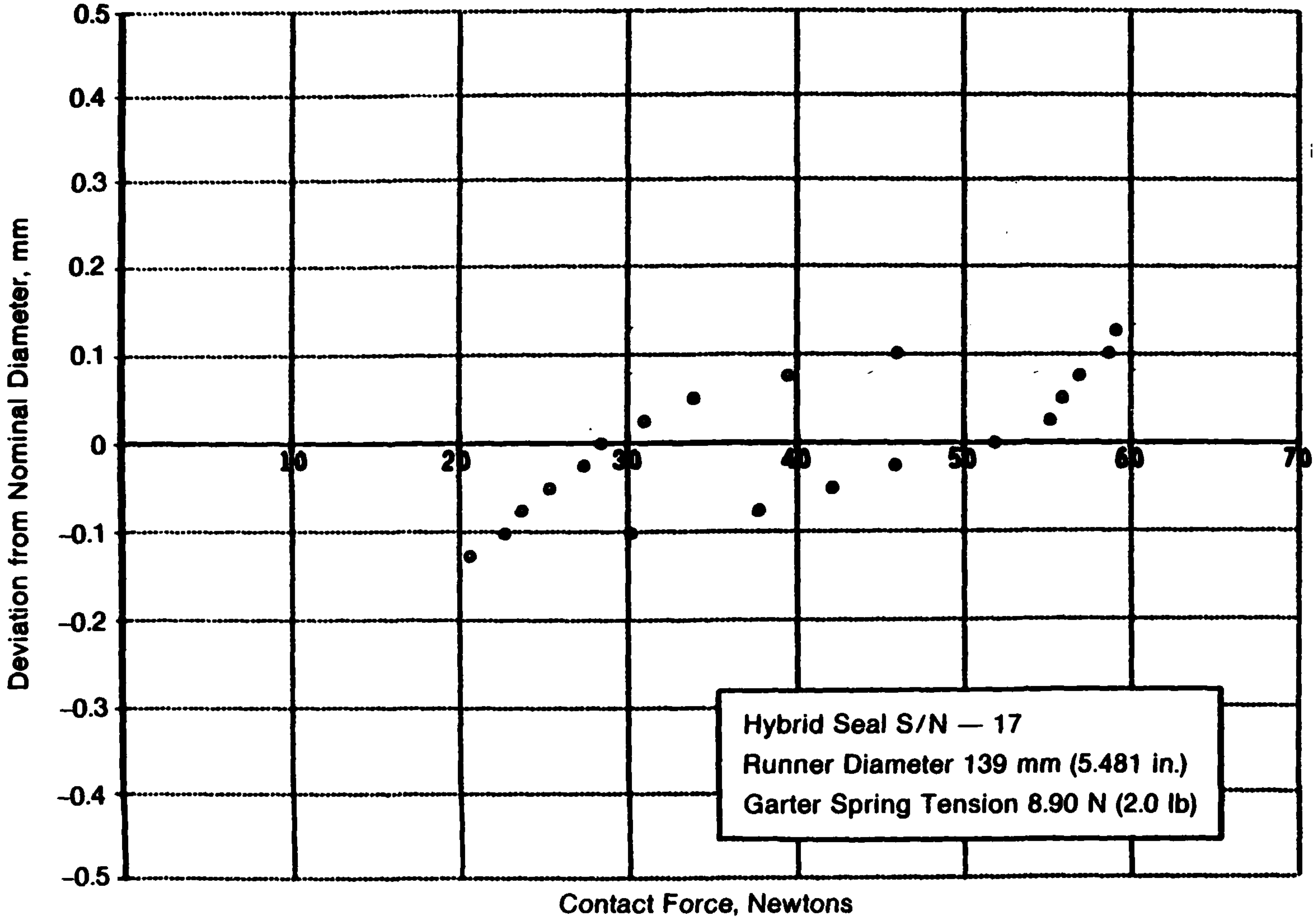

Figure 22. Hybrid Elastomer Seal (No. 17) Runner Contact Force.

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TABLE 4. SEAL FORCE MEASUREMENT RESULTS

Seal No.	Seal Force Large Seal
8	28 N (5.6 lb)
9	31 N (6.7 lb)
10	29 N (6.5 lb)
11	39 N (8.8 lb)
12	38 N (8.5 lb)
14	44 N (9.9 lb)
16	65 N (12.0 lb)
17	40 N (9.0 lb)

TABLE 5. DYNAMIC TEST RESULTS - SURFACE FINISH AND WEAR

Seal No.	Test Time (hr)	Runner Surface Finish (GLA)		Carbon Segment Wear			
				Oil Side		Air Side	
		Pre-Test mm (μin.)	Post-Test mm (μin.)	Maximum mm (in.)	Minimum mm (in.)	Maximum mm (in.)	Minimum mm (in.)
8	27	3.56×10^{-4} (14)	1.09×10^{-3} (43)	0.020 (0.0008)	0.002 (0.0001)	0.048 (0.0019)	0.023 (0.0009)
9	2	3.56×10^{-4} (14)	4.06×10^{-4} (16)	0.020 (0.0008)	0.000 (0.0000)	0.025 (0.0010)	0.002 (0.0001)
10	21	4.06×10^{-4} (16)	1.04×10^{-3} (41)	0.002 (0.0001)	0.010 (0.0004)	0.018 (0.0007)	0.000 (0.0000)
11	27	4.57×10^{-4} (18)	7.62×10^{-4} (30)	0.066 (0.0026)	0.028 (0.0011)	0.025 (0.0010)	0.008 (0.0003)
12	27	4.57×10^{-4} (18)	9.40×10^{-4} (37)	0.008 (0.0003)	0.000 (0.0000)	0.018 (0.0007)	0.005 (0.0002)
13	9	3.81×10^{-4} (15)	1.27×10^{-3} (50)	0.008 (0.0003)	0.000 (0.0000)	0.015 (0.0006)	0.002 (0.0001)
14	16	3.81×10^{-4} (15)	1.27×10^{-3} (50)	0.030 (0.0012)	0.010 (0.0004)	0.028 (0.0011)	0.010 (0.0004)
16	18	4.23×10^{-4} (19)	7.62×10^{-4} (30)	0.013 (0.0005)	0.000 (0.0000)	0.028 (0.0011)	0.010 (0.0004)
17	18	4.57×10^{-4} (18)	1.52×10^{-3} (60)	0.002 (0.0010)	0.005 (0.0002)	0.028 (0.0011)	0.010 (0.0004)

TABLE 6. DYNAMIC TEST RESULTS - LEAK RATE AND FRICTION TORQUE

Velocity m/sec (ft/min)	ΔP MPa (lb/in.^{2})	SEAL 8 Leak Rate cc/hr	SEAL 8 Friction Torque N·m (ft-lb)	SEAL 9 Leak Rate cc/hr	SEAL 9 Friction Torque N·m (ft-lb)	SEAL 10 Leak Rate cc/hr	SEAL 10 Friction Torque N·m (ft-lb)	SEAL 11 Leak Rate cc/hr	SEAL 11 Friction Torque N·m (ft-lb)
50.8 (10,000)	0 (0)	42.5	2.6 (1.9)	105.0	2.0 (1.5)	41.5	2.0 (1.5)	47.2	2.4 (1.8)
	6.9×10^{-3} (1)	74.6	2.6 (1.9)	Test Terminated for Inspection		64.5	2.6 (1.9)	53.0	2.2 (1.6)
	1.4×10^{-2} (2)	43.3	2.8 (2.1)			47.9	2.8 (2.1)	77.6	2.6 (1.9)
76.2 (15,000)	0 (0)	4.4	2.0 (1.5)			53.0	2.2 (1.6)	7.1	1.4 (1.0)
	6.9×10^{-3} (1)	2.0	2.0 (1.5)			51.7	2.0 (1.5)	7.0	1.4 (1.0)
	1.4×10^{-2} (2)	10.0	1.8 (1.3)			36.6	2.2 (1.6)	9.3	1.5 (1.1)
101.6 (20,000)	0 (0)	2.1	1.5 (1.1)			105.0	1.4 (1.0)	2.8	1.2 (0.9)
	6.9×10^{-3} (1)	1.9	1.5 (1.1)			Test Terminated for Inspection		5.4	1.5 (1.0)
	1.4×10^{-2} (2)	3.5	1.5 (1.1)					15.8	2.3 (1.7)
		SEAL 12		SEAL 13		SEAL 14		SEAL 16	
50.8 (10,000)	0 (0)	99.4	2.7 (2.0)	17.7	1.9 (1.4)	37.5	2.3 (1.7)	62.5	3.1 (2.3)
	6.9×10^{-3} (1)	128.0	2.7 (2.0)	65.6	2.4 (1.8)	225.0	3.2 (2.4)	200.0	3.4 (2.5)
	1.4×10^{-2} (2)	186.0	2.7 (2.0)	208.0	2.6 (1.9)	400.0	3.8 (2.8)	225.0	3.7 (2.7)
76.2 (15,000)	0 (0)	181.0	2.0 (1.5)	Test Terminated for Inspection		Test Terminated for Inspection		50.0	3.1 (2.3)
	6.9×10^{-3} (1)	217.0	2.0 (1.5)					25.0	3.2 (2.4)
	1.4×10^{-2} (2)	221.0	2.3 (1.7)					200.0	3.2 (2.4)
101.6 (20,000)	0 (0)	188.0	1.5 (1.1)					50.0	3.1 (2.3)
	6.9×10^{-3} (1)	173.0	1.4 (1.0)					25.0	3.0 (2.2)
	1.4×10^{-2} (2)	200.0	1.4 (1.0)					50.0	3.2 (2.4)
		SEAL 17							
50.8 (10,000)	0 (0)	2.5	2.7 (2.0)						
	6.9×10^{-3} (1)	62.5	2.7 (2.0)						
	1.4×10^{-2} (2)	215.0	2.8 (2.1)						
76.2 (15,000)	0 (0)	70.0	2.6 (1.9)						
	6.9×10^{-3} (1)	112.0	2.7 (2.0)						
	1.4×10^{-2} (2)	125.0	2.7 (2.0)						
101.6 (20,000)	0 (0)	40.0	2.6 (1.9)						
	6.9×10^{-3} (1)	200.0	2.6 (1.9)						
	1.4×10^{-2} (2)	125.0	2.0 (2.0)						

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6.0 DISCUSSION OF TEST RESULTS

It is evident from the dynamic test results that most test seals exhibited excessive leakage, high friction torque, and high wear rates. The seals whose testing was terminated prior to the completion of the prescribed test sequence were examined for possible rework, but visual examination did not disclose any logical methodology for improving performance. These shortened tests were not resumed due to carbon segment damage during the disassembly or reassembly process.

Post-test examinations of test seals disclosed several features which might have contributed to high leakage. A photograph of a typical post-test seal is shown in Figure 23. The close-up photographs of the seal-shaft contact area identify several problem areas such as circumferential scratches due to wear debris (A), separation of segments due to the introduction of wear debris into the interface (B), and loss of seal insert material (C). The seal segment distress visible on the photographs is typical of all the seals tested. In addition to the seal contact area distress, seal wear may be indicative of the seals' high leakage rates.

There are strong indicators that more wear occurs on the air side sealing segments than on the oil side segments, leading to the possibility of seal rollover as a possible cause of high leakage rates [3]. Seal rollover is a common feature of ordinary lip seals.

The seal runners also showed severe wear, as exemplified by the pre- and post-test surface finish measurements of seal runners; see Table 5. Severe scoring of the runner surface over the short amount of run time does not provide the confidence needed for long-term satisfactory seal operation.

When high seal leakage rates were recorded during the test program, a simple test was performed to determine whether undershaft cooling oil was leaking into the seal discharge port. For short periods of time, all undershaft cooling flow was terminated; since no noticeable change in leakage flow rates was noted, it was concluded that all the measured leakage did in fact come from the seal.

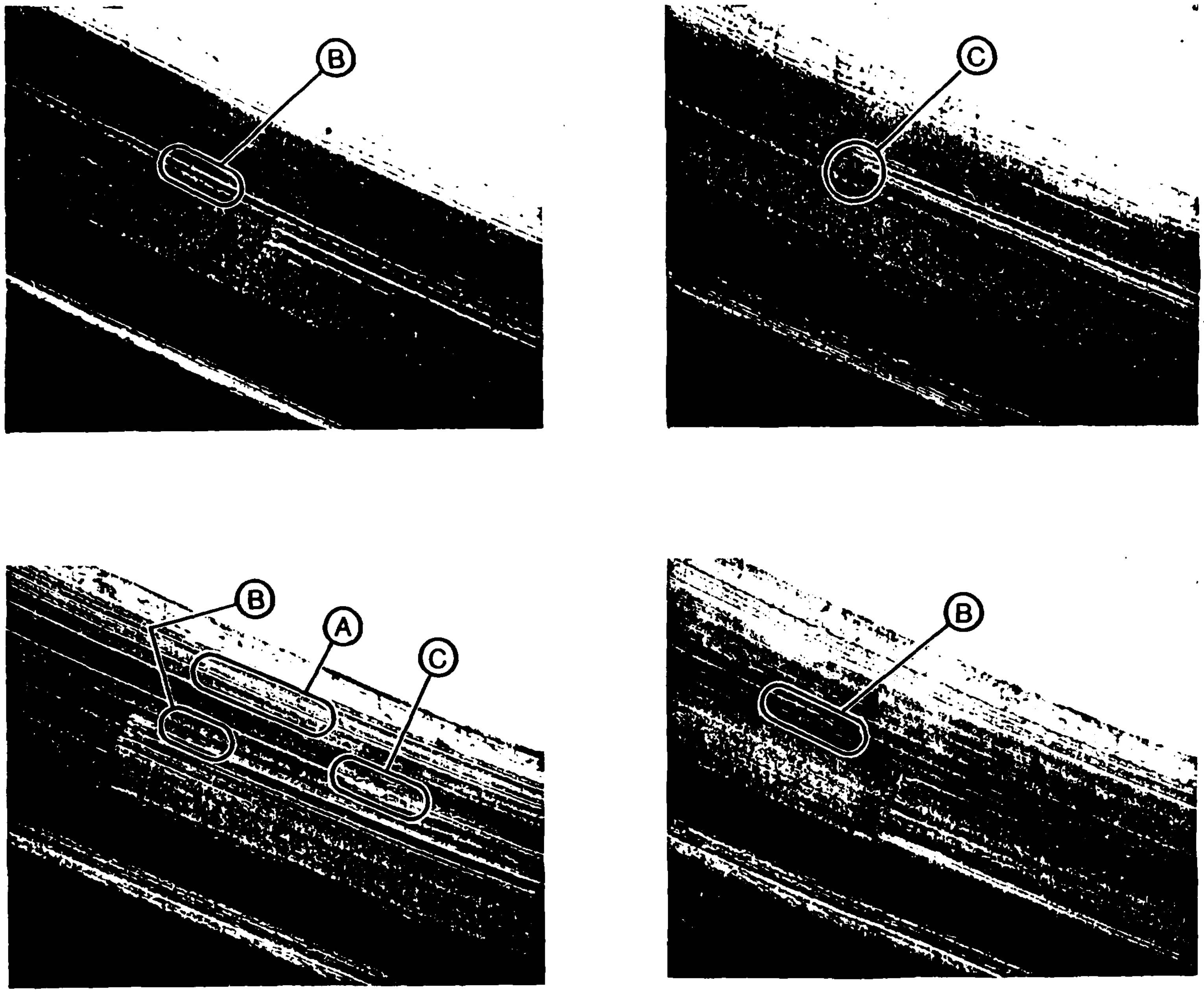

Figure 23. Close-up of Shaft Seal Contact Area.

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A review of the test procedure was also made to establish a reasonable cause for the high leakage rates recorded. Several test parameters, upon post-test review, seem severe when compared to the actual conditions that would be experienced in the field. Some conditions which seem excessive are:

- 6.9×10^{-3} MPa (1 psi) and 1.4×10^{-2} MPa (2 psi) differential pressure across test seal
- Surface velocities up to three times greater than those found in existing helicopters
- Excessive oil impinging on seal carbons; for six tests, oil at a flow rate of 1 gpm was jetted directly against the seal carbons. For three test conditions, this rate was reduced by 1/3 and was directed more against the seal runner but still in very close proximity to the seal carbons.

Additional work on hybrid elastometric seals [4] performed after this program was initiated showed that a seal with zero leakage could be produced by employing wind-back grooves in the carbon sealing ring bores. However, time and cost constraints prohibited the incorporation of the results of the referenced work into this program.

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7.0 CONCLUSIONS

Specific conclusions to be drawn from the program results include:

1. Manufacturing technology for producing the hybrid elastomer seal in production lot sizes of 500 to 1000 units has been successful. The seal as presently designed can be readily manufactured and is relatively simple to assemble.

2. The seal has the demonstrated ability to sustain very high rubbing velocities, up to 102 m/sec (20,000 ft/min) indicating that the seal does show merit.

3. High leakage rates exhibited by the present seal design were attributed to a combined result of design deficiencies and test conditions of excessive severity. Seals with wind-back grooves [4] have demonstrated no leakage at test conditions of this type.

4. Power losses approached 2000 watts (3 hp) at 14,000 rpm. Post-test examination of test seals indicated no distress from overheating.

5. Carbon ring insert wear exceeded 0.025 mm (0.001 in.) over a test period of between 18 to 27 hours. This short test time did not provide the opportunity to evaluate long-term wear. The high wear demonstrated by these test seals is not necessarily indicative of the wear experienced by seals operating for extended periods of time, since initial run-in wear of carbon seals is characteristically greater than subsequent long-term wear. The use of AISI type 304 series stainless steel as the seal runner provides long-term corrosion resistance, but the material's lack of hardness, approximately R_c 15 as opposed to conventional seal runner hardness in the range R_c 50/60, contributes to the high wear rates noted.

6. The tapered bore configuration on the carbon graphite sealing segments is not cost-effective since it is very rapidly worn away during the run-in process.

7. Cost* of providing seals in large lots (at least 30 units) can approach $500 for the small seal and $650 for the large seal, depending on burden rates and amortization rate for tooling.

*1982 dollars.

8.0 REFERENCES

1. Ludwig, L.P., Circumferential Shaft Seal, U.S. Patent No. 4,212,477, July 1980.

2. O'Brien, M., Development of a Synergistic Type Shaft Seal for Aircraft Transmissions, Avco Lycoming Report 76-50, NASA-CR-135084, August 1976.

3. O'Brien, M., Transmission Seal Development, Avco Lycoming Report 77-65, NASA-CR-135372, October 1977.

4. O'Brien, M., Experimental Evaluation of a High-Speed Seal for an Aircraft Transmission, Avco Lycoming Report 79-48, NASA-CR-159709, August 1979.

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APPENDIX A

LIST OF DRAWINGS

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HYBRID-ELASTOMER SEAL DRAWINGS

- **Small-Diameter Seal**

PL399B09	Parts List - 2-1/2 Inch Diameter Seal
399B09	Assembly - 2-1/2 Inch Diameter Seal
399C04	Outer Seal Ring
399C03	Inner Seal Ring
399D01	Molded Elastomer
399D05	Carbon Seal Ring
399B11-P1	Garter Spring

- **Large-Diameter Seal**

PL399B10	Parts List - 5-1/2 Inch Diameter Seal
399B10	Assembly - 5-1/2 Inch Diameter Seal
399C07	Outer Seal Ring
399C06	Inner Seal Ring
399D02	Molded Elastomer
399D08	Carbon Seal Ring
399B11-P2	Garter Spring

- **Tooling**

399D20	Assembly Static Seal Tester
399D21	Machining Assembly (5-1/2 Inch Diameter Seal)
399D22	Machining Assembly (2-1/2 Inch Diameter Seal)
399B12	Arbor (2-1/2 Inch Diameter Seal)
399C13	Arbor (5-1/2 Inch Diameter Seal)
399C14	Rear Cover
399C15	Support Tube
399C16	Seal Seat
399B17	Diffuser
399C18	OD Seal Ring
399C19	Cover
399C26	Assembly Tool for 399B09 Seal
399C27	Assembly Tool for 399B10 Seal
399C28	Garter Spring Insertion Tool
SK-C-5778	Seal Force Gage

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APPENDIX B

INSPECTION REPORTS - STATIC TESTING OF SMALL-DIAMETER SEALS

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2½" = 2 turn = 12
Sent to NASA

Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399809 Seal Serial No. 2

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 2-1-1	.1294	.1291	.1279
• 2-1-2	.1277	.1276	.1277
• 2-1-3	.1280	.1289	.1294
• 2-2-4	.1285	.1284	.1274
• 2-2-5	.1282	.1286	.1285
• 2-2-6	.1274	.1282	.1281

Static Test Results:

- Light Leakage (percent); 0 Bluing 55%
- Air Leakage. . . . . . ; Pressure .2 lb/in^2, Flow 150 cc/l

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

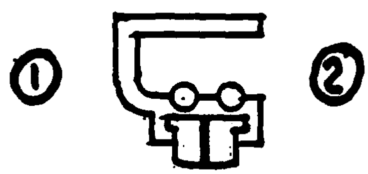
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

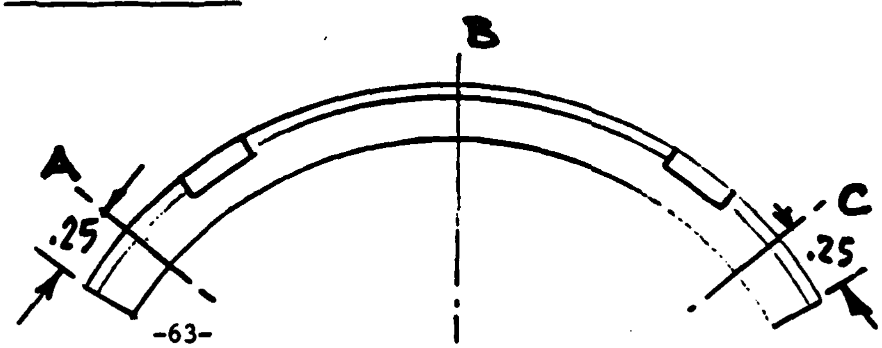
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399809 Seal Serial No. 3

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 3-1-1	.1282	.1276	.1272
• 3-1-2	.1283	.1286	.1286
• 3-1-3	.1274	.1283	.1285
• 3-2-4	.1273	.1283	.1285
• 3-2-5	.1284	.1286	.1284
• 3-2-6	.1281	.1278	.1275

Static Test Results:

- Light Leakage (percent); 0 Blueing 75%
- Air Leakage. . . . . . ; Pressure 3 lb/in^2, Flow 100 Scc/1

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

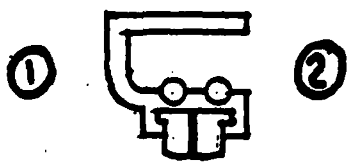
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

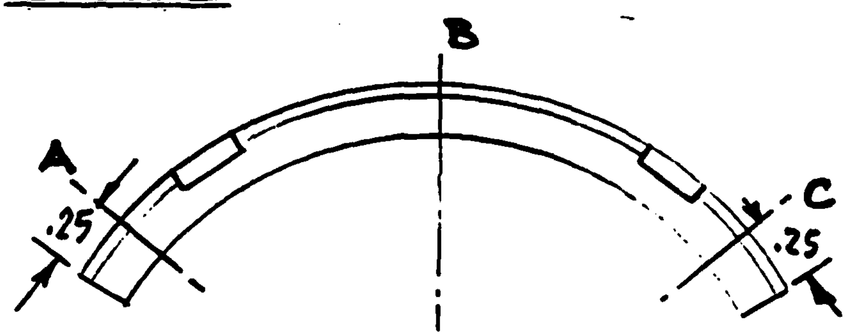
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399B09 Seal Serial No. 4

Garter Spring Tension: 1, 1.25 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 4-1-1	.1280	.1281	.1284
• 4-1-2	.1281	.1280	.1282
• 4-1-3	.1283	.1280	.1278
• 4-2-4	.1277	.1285	.1286
• 4-2-5	.1275	.1228	.1276
• 4-2-6	.1275	.1283	.1286

Static Test Results:

- Light Leakage (percent); 0 Blueing 85%
- Air Leakage. . . . . . ; Pressure 3 lb/in^2, Flow 30 cc/m

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

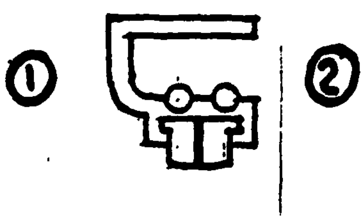
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

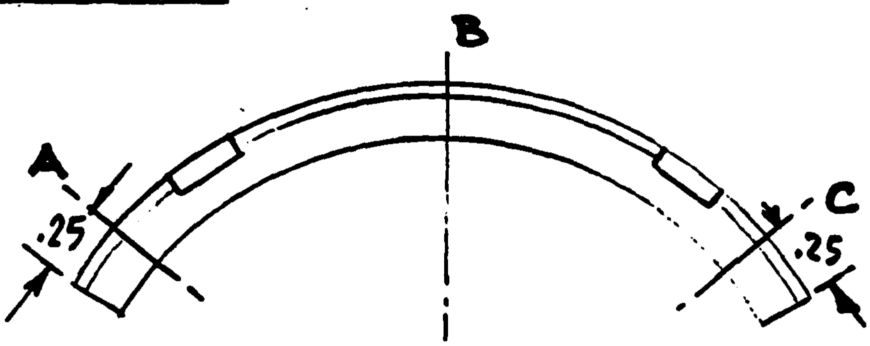
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399809 Seal Serial No. 5

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 5-1-1	.1287	.1281	.1279
• 5-1-2	.1278	.1276	.1287
• 5-1-3	.1278	.1280	.1281
• 5-2-4	.1278	.1280	.1279
• 5-2-5	.1281	.1290	.1288
• 5-2-6	.1289	.1285	.1288

Static Test Results:

- Light Leakage (percent); 0 Blurry 85%
- Air Leakage. . . . . . ; Pressure 3 lb/in^2, Flow 25 cc/1

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

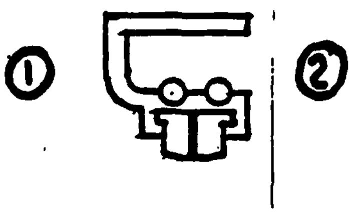
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

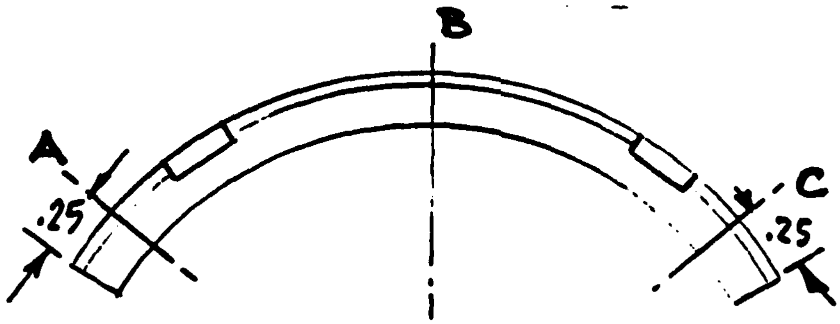
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RM Green

Seal Drawing No. 399809 Seal Serial No. 6

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 6-1-1	.1274	.1286	.1289
• 6-1-2	.1278	.1281	.1276
• 6-1-3	.1291	.1286	.1282
• 6-2-4	.1275	.1280	.1284
• 6-2-5	.1283	.1286	.1287
• 6-2-6	.1287	.1284	.1277

Static Test Results:

- Light Leakage (percent); 0 Bluing 80%
- Air Leakage. . . . . . ; Pressure 3 lb/in^2, Flow 55 cc/m

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

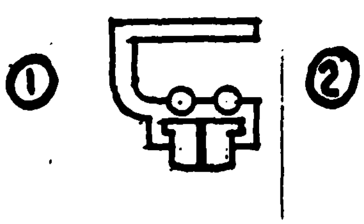
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

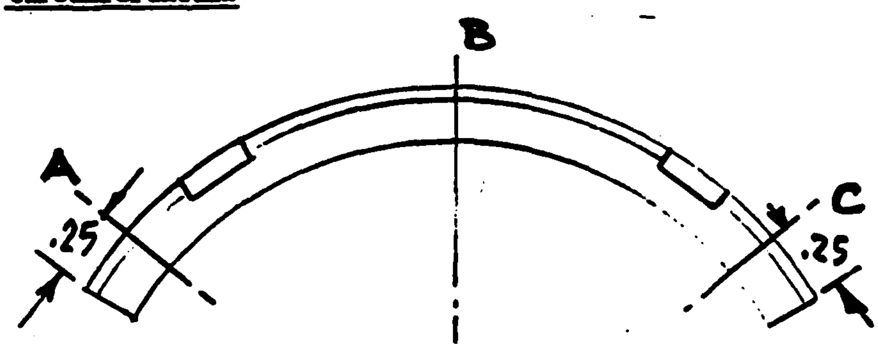
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399809 Seal Serial No. 7

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 7-1-1	.1277	.1275	.1288
• 7-1-2	.1284	.1275	.1279
• 7-1-3	.1288	.1285	.1283
• 7-2-4	.1279	.1278	.1280
• 7-2-5	.1282	.1281	.1286
• 7-2-6	.1278	.1284	.1278

Static Test Results:

- Light Leakage (percent); 0 Bluing 70%
- Air Leakage. . . . . . ; Pressure 1.5 lb/in^2, Flow 150 cc/

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

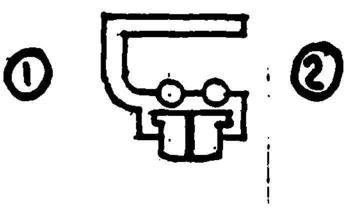
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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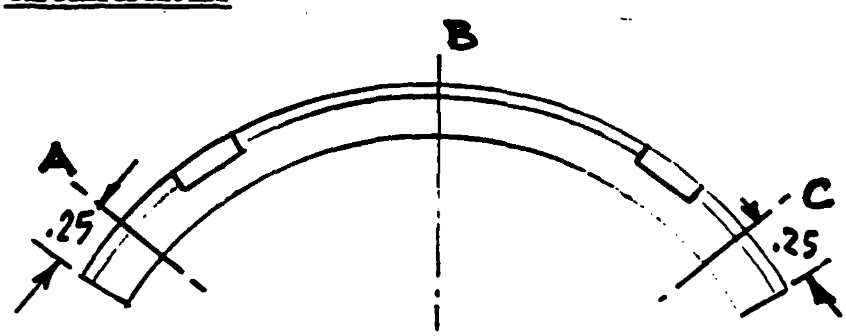


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMG

Seal Drawing No. 399B09 Seal Serial No. 8

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 8-1-1	.1282	.1281	.1281
• 8-1-2	.1283	.1277	.1280
• 8-1-3	.1280	.1277	.1278
• 8-2-4	.1280	.1281	.1291
• 8-2-5	.1283	.1284	.1283
• 8-2-6	.1290	.1277	.1281

Static Test Results:

- Light Leakage (percent); 0 Blueing 80%
- Air Leakage. . . . . . ; Pressure 3 lb/in^2, Flow 90 cc/m

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

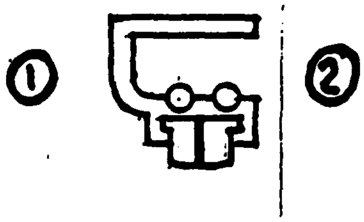
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

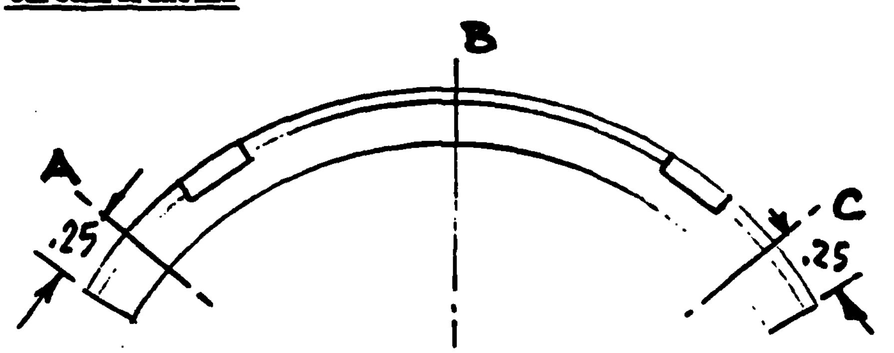
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMG[illegible]

Seal Drawing No. 379309 Seal Serial No. 9

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 9-1-1	.1279	.1287	.1288
• 9-1-2	.1287	.1284	.1287
• 9-1-3	.1288	.1287	.1277
• 9-2-4	.1282	.1275	.1286
• 9-2-5	.1288	.1279	.1277
• 9-2-6	.1284	.1285	.1281

Static Test Results:

- Light Leakage (percent); 0 Bluing 65%
- Air Leakage. . . . . . ; Pressure 1.25 lb/in^2, Flow 150 cc/

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

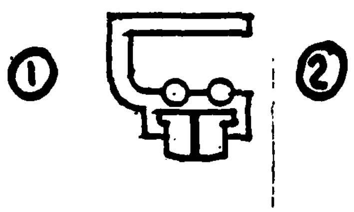
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

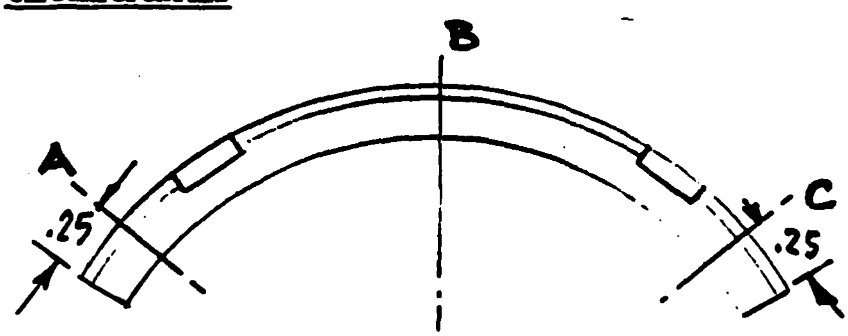
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399809 Seal Serial No. 10

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 10-1-1	.1279	.1285	.1285
• 10-1-2	.1286	.1284	.1281
• 10-1-3	.1284	.1276	.1276
• 10-2-4	.1281	.1289	.1297
• 10-2-5	.1290	.1286	.1290
• 10-2-6	.1291	.1278	.1274

Static Test Results:

- Light Leakage (percent); 0 Blueing 50%
- Air Leakage. . . . . . ; Pressure .13 lb/in^2, Flow 150 cc/1

Carbon Ring Identification: (XX), - X_2 - X_3

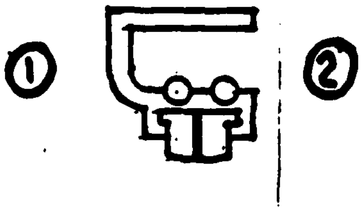
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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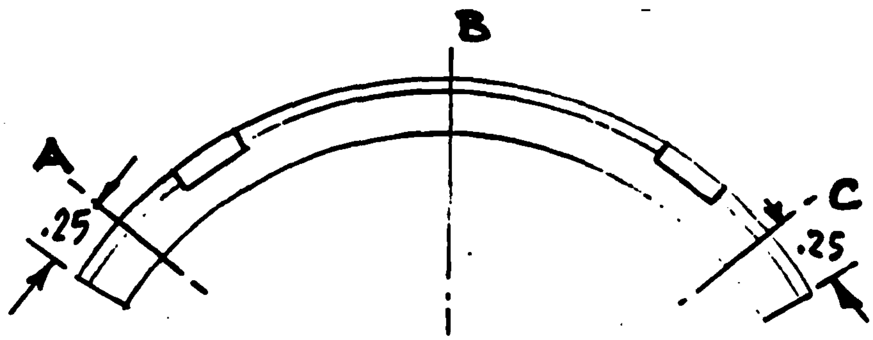


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399R09 Seal Serial No. 11

Garter Spring Tension: 1, 1.75 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 11-1-1	.1282	.1282	.1283
• 11-1-2	.1284	.1282	.1284
• 11-1-3	.1284	.1282	.1281
• 11-2-4	.1274	.1274	.1278
• 11-2-5	.1281	.1288	.1292
• 11-2-6	.1292	.1291	.1277

Static Test Results:

- Light Leakage (percent); 0 Blueing 70%
- Air Leakage. . . . . . ; Pressure 1.5 lb/in^2, Flow 150 cc/m

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

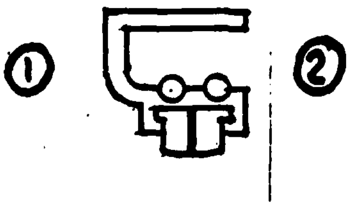
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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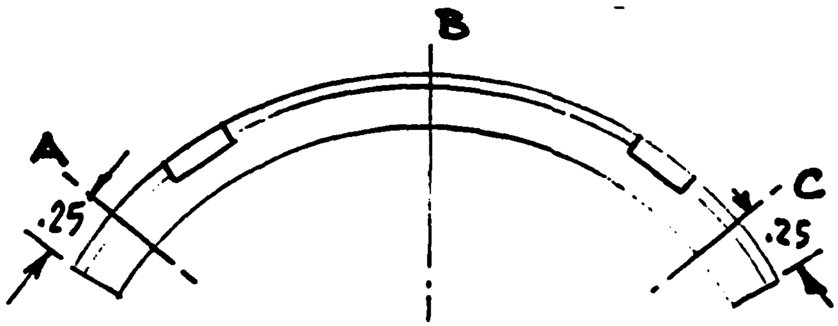


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 6-26-81 By: RMGreen

Seal Drawing No. 399609 Seal Serial No. 12

Garter Spring Tension: 1, 1.25 lb.; 2, 1.75 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 12-1-1	.1284	.1284	.1283
• 12-1-2	.1276	.1283	.1283
• 12-1-3	.1287	.1287	.1277
• 12-2-4	.1285	.1280	.1280
• 12-2-5	.1278	.1285	.1287
• 12-2-6	.1286	.1278	.1286

Static Test Results:

- Light Leakage (percent); 0 Blueing 60%
- Air Leakage. . . . . . ; Pressure .2 lb/in^2, Flow 150 cc/

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

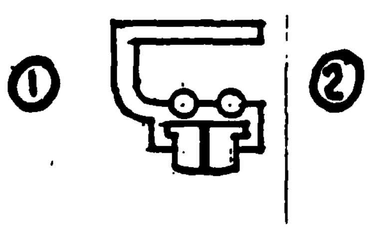
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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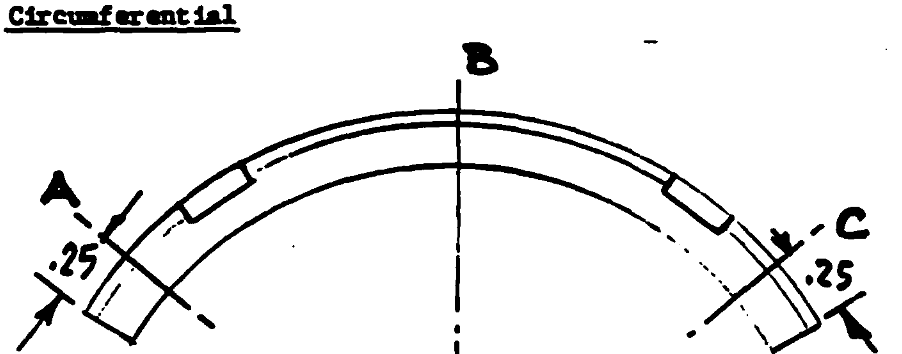

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APPENDIX C

INSPECTION REPORTS - STATIC TESTING OF LARGE-DIAMETER SEALS

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Insmaco 11/24/81

Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RM Greene

Seal Drawing No. 399808 Seal Serial No. 8

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 8-1-1	.1627	.1623	.1625
• 8-1-2	.1625	.1626	.1628
• 8-1-3	.1628	.1627	.1629
• 8-2-4	.1626	.1626	.1625
• 8-2-5	.1626	.1627	.1627
• 8-2-6	.1627	.1627	.1628

Static Test Results:

- Light Leakage (percent); 0 Blueing Check 50%
- Air Leakage. . . . . . ; Pressure 3 lb/in^2, Flow 150 cc/h

Liner Run-out .0008

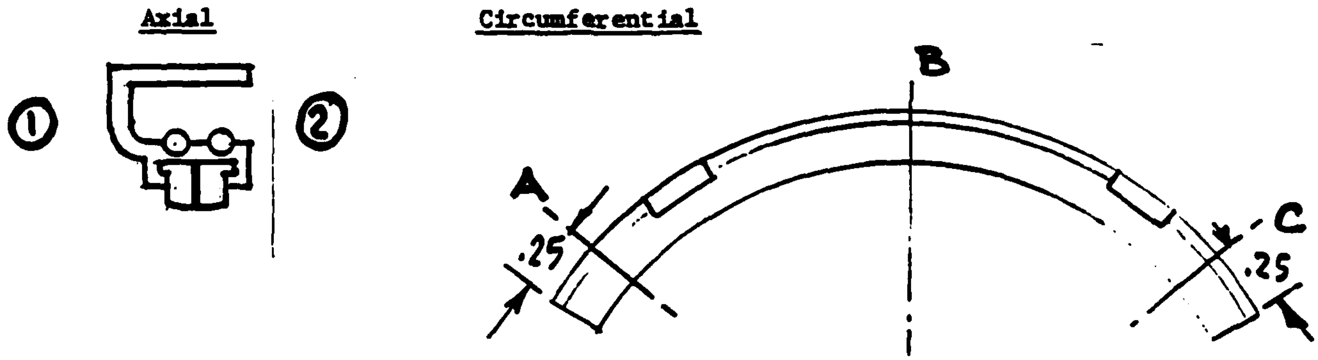
Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:



Hybrid Elastomer Seal: Contract - NASA NAS3-20837 *Post Test Insp.*

Inspection Report: Date: *12-15-81* By: *R. M. Greene*

Seal Drawing No. *399808* Seal Serial No. *8*

Garter Spring Tension: 1, *(2)* lb.; 2, *(2)* lb.

Carbon Ring Dimensions:

Identification	A	B	C
• *8-1-1*	*.1616*	*.1612*	*.1613*
• *8-1-2*	*.1609*	*.1617*	*.1617*
• *8-1-3*	*.1615*	*.1611*	*.1610*
• *8-2-4*	*.1624*	*.1624*	*.1621*
• *8-2-5*	*.1621*	*.1623*	*.1622*
• *8-2-6*	*.1623*	*.1623*	*.1620*

Seal

Seal Runner Runout .0006"

Static Test Results:

- Light Leakage (%); ________ • Blueing Check (%) ________
- Air Leakage. . . . . . ; Pressure ________ lb/in^2, Flow ________ cc/hr.

Carbon Ring Identification: (XX), - X_2 - X_3

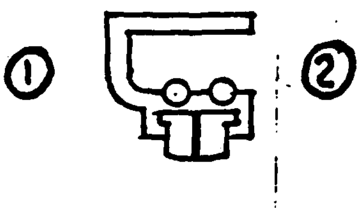
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

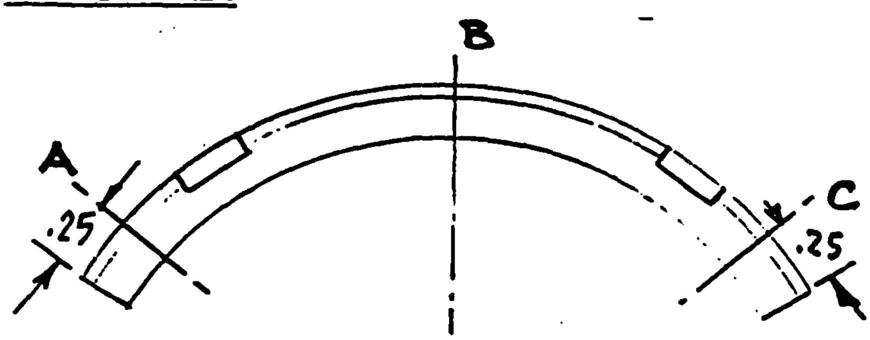
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RMGreen

Seal Drawing No. 399B08 Seal Serial No. 9

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 9-1-1	.1625	.1621	.1631
• 9-1-2	.1622	.1625	.1623
• 9-1-3	.1630	.1629	.1626
• 9-2-4	.1623	.1625	.1629
• 9-2-5	.1621	.1626	.1625
• 9-2-6	.1627	.1620	.1620

Seal leaked badly
- was [illegible] on dimension[illegible]

Static Test Results:

- Light Leakage (percent); 0 Blueing Check (%) 90%
- Air Leakage. . . . . . ; Pressure 4.25 lb/in^2, Flow 100 cc/h

Liner Run-out [illegible]

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

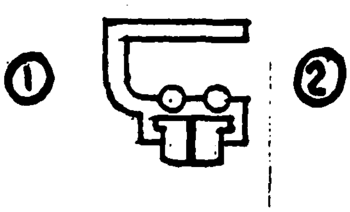
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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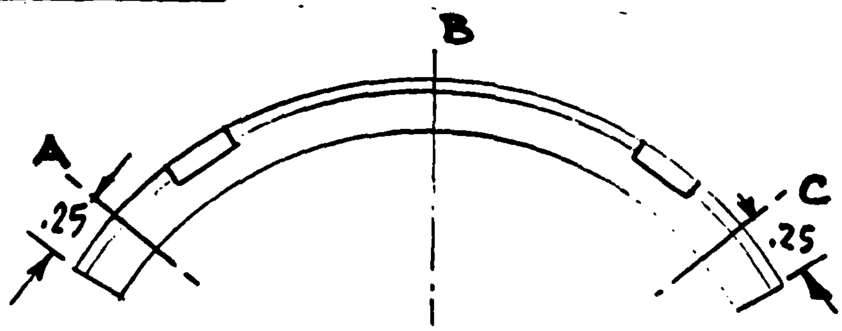


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date:________________ By:______________

Seal Drawing No. _______________ Seal Serial No. 9

Garter Spring Tension: 1, __________ lb.; 2, __________ lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 9-1-1	.1624	.1618	.1624
• 9-1-2	.1619	.1623	.1620
• 9-1-3	.1628	.1619	.1620
• 9-2-4	.1620	.1622	.1621
• 9-2-5	.1621	.1624	.1625
• 9-2-6	.1627	.1620	.1620

Static Test Results:

- Light Leakage (percent); ____________
- Air Leakage. . . . . . ; Pressure __________ lb/in^2, Flow __________ cc/t

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

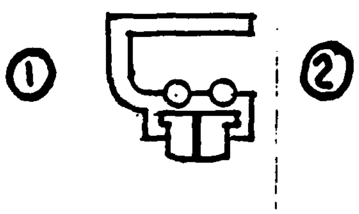
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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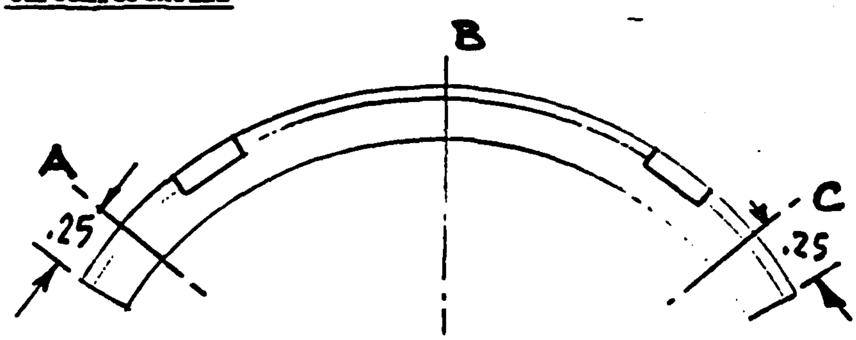


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RM [illegible]

Seal Drawing No. 399808 Seal Serial No. 10

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 10-1-1	.1626	.1627	.1628
• 10-1-2	.1627	.1625	.1627
• 10-1-3	.1622	.1624	.1625
• 10-2-4	.1630	.1631	.1630
• 10-2-5	.1629	.1638	.1631
• 10-2-6	.1630	.1632	.1630

Static Test Results:

- Light Leakage (percent); 0 Bearing Check (%) 85%
- Air Leakage. . . . . . ; Pressure 1 lb/in², Flow 150 cc/h

Liner Runout .0001

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

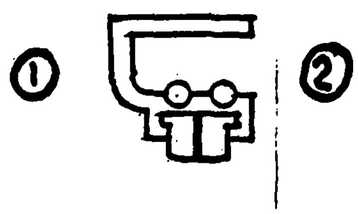
$(XX)_1$ = Set Sequence No.

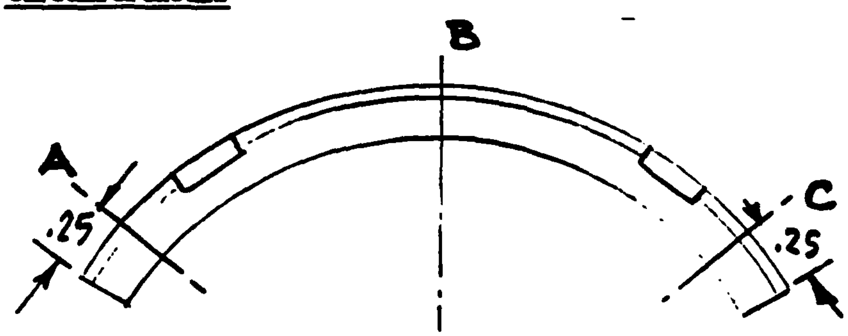
X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial **Circumferential**





Hybrid Elastomer Seal: Contract - NASA NAS3-20837 POST TEST INSPECTION

Inspection Report: Date: 1-5-82 By: RM Greene

Seal Drawing No. 399808 Seal Serial No. 10

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 10-1-1	.1622	.1622	.1626
• 10-1-2	.1625	.1618	.1621
• 10-1-3	.1622	.1617	.1625
• 10-2-4	.1628	.1629	.1628
• 10-2-5	.1628	.1637	.1628
• 10-2-6	.1628	.1630	.1629

Static Test Results:

- Light Leakage (%): ________ • Blueing Check (%) ________
- Air Leakage. . . . . . ; Pressure ________ lb/in^2, Flow ______ cc/hr

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

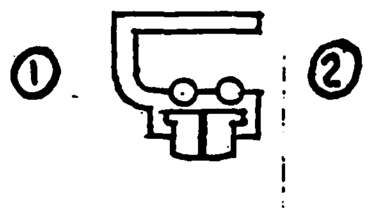
$(XX)_1$ = Set Sequence No.

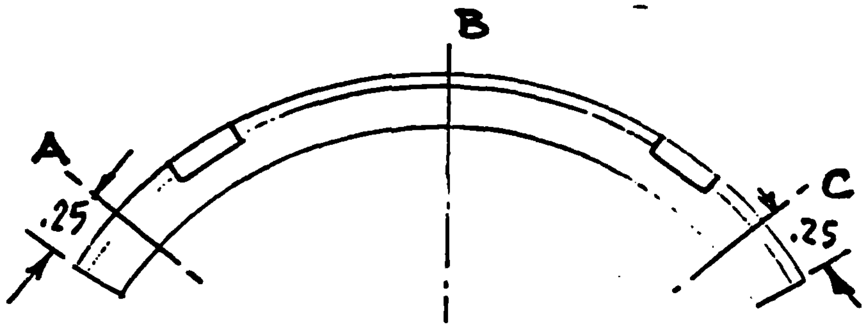
X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial **Circumferential**





Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RMGreene

Seal Drawing No. 399808 Seal Serial No. 11

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 11-1-1	.1614	.1628	.1622
• 11-1-2	.1626	.1624	.1619
• 11-1-3	.1624	.1627	.1627
• 11-2-4	.1621	.1622	.1628
• 11-2-5	.1628	.1627	.1628
• 11-2-6	.1623	.1624	.1623

Static Test Results:

- Light Leakage (percent); .1% Blueing Check (%) 75
- Air Leakage. . . . . . ; Pressure 5 lb/in^2, Flow 120 cc/h

Liner Runout .0011

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

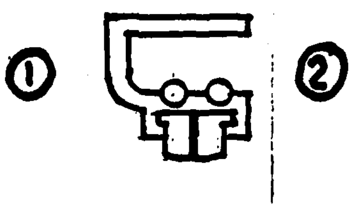
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

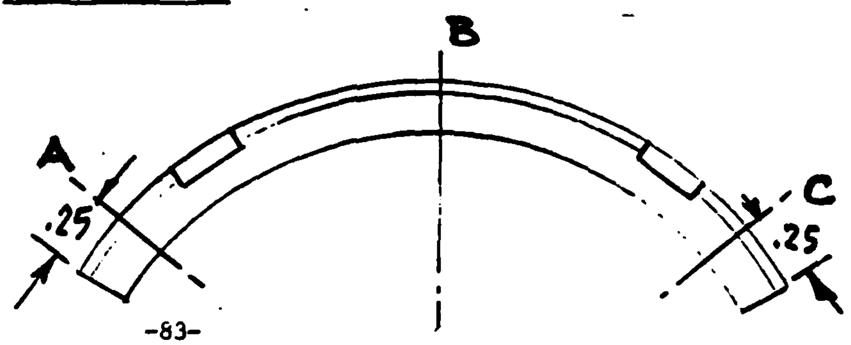
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837 Post Test

Inspection Report: Date: 1-20-82 By: RM Greene

Seal Drawing No. 399808 Seal Serial No. 11

Carter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 11-1-1	.1603	.1602	.1606
• 11-1-2	.1605	.1603	.1604
• 11-1-3	.1609	.1606	.1606
• 11-2-4	.1616	.1617	.1620
• 11-2-5	.1621	.1617	.1618
• 11-2-6	.1620	.1620	.1617

Static Test Results:

- Light Leakage (%); ________ • Blueing Check (%) ________
- Air Leakage. . . . . . ; Pressure ________ lb/in^2, Flow ________ cc/hr

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

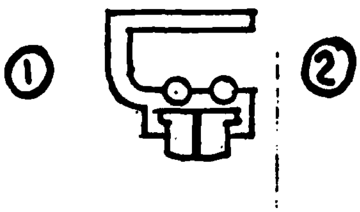
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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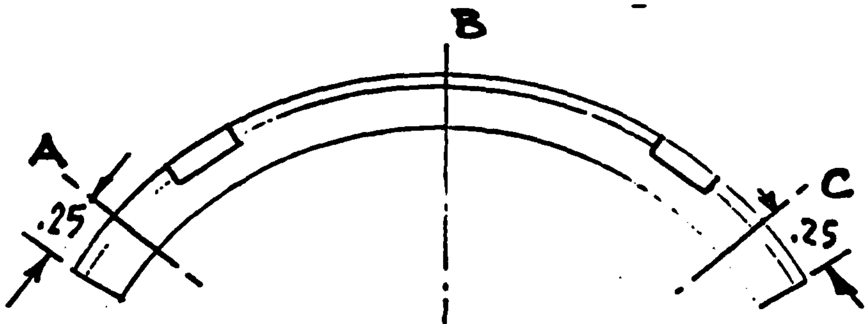


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RM Greene

Seal Drawing No. 399808 Seal Serial No. 12

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 12-1-1	.1628	.1629	.1628
• 12-1-2	.1628	.1627	.1629
• 12-1-3	.1628	.1629	.1629
• 12-2-4	.1624	.1623	.1622
• 12-2-5	.1620	.1627	.1622
• 12-2-6	.1625	.1622	.1626

Static Test Results:

- Light Leakage (percent); 0 Blueing 75%
- Air Leakage. . . . . . ; Pressure 2 lb/in^2, Flow 150 cc/h

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

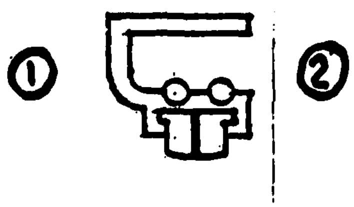
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

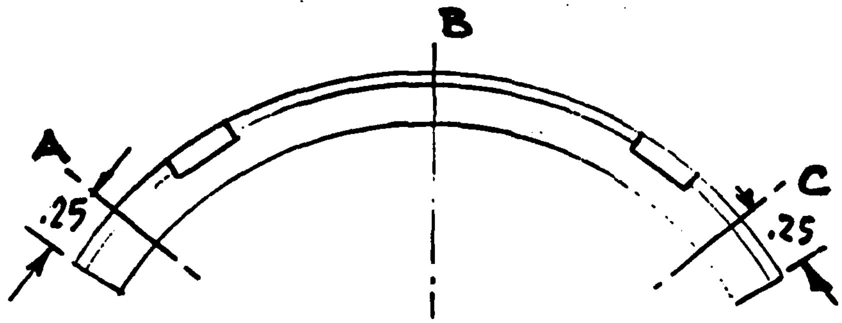
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837 Post Test

Inspection Report: Date: 3-2-82 By: RM G[illegible]

Seal Drawing No. 399808 Seal Serial No. 12

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
12-1-1	.1622	.1622	.1623
12-1-2	.1622	.1620	.1623
12-1-3	.1626	.1622	.1623
12-2-4	.1624	.1621	.1621
12-2-5	.1620	.1624	.1621
12-2-6	.1625	.1620	.1626

Static Test Results:

- Light Leakage (%): ________ • Blueing Check (%) ________
- Air Leakage. . . . . . ; Pressure ________ lb/in^2, Flow ________ cc/hr.

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

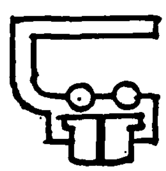
$(XX)_1$ = Set Sequence No.

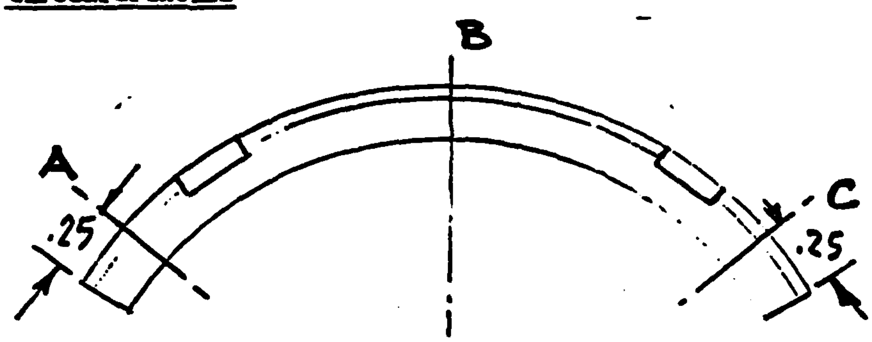
X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial **Circumferential**

1  2



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RMGreen

Seal Drawing No. 399B08 Seal Serial No. 13

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 13-1-1	.1630	.1631	.1629
• 13-1-2	.1632	.1626	.1631
• 13-1-3	.1628	.1628	.1631
• 13-2-4	.1629	.1628	.1627
• 13-2-5	.1627	.1629	.1629
• 13-2-6	.1627	.1626	.1629

Static Test Results:

- Light Leakage (percent); 0 Blueing 85%
- Air Leakage. . . . . . ; Pressure 4.4 lb/in^2, Flow 70 cc/h

---

Carbon Ring Identification: (XX), - X_2 - X_3

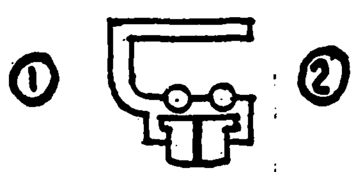
(XX)$_1$ = Set Sequence No.

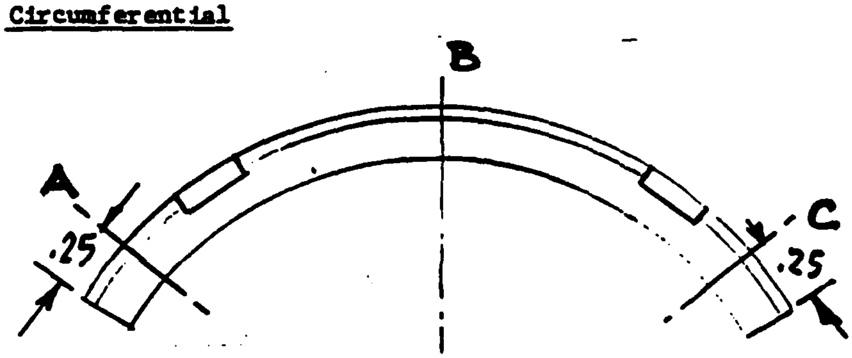
X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial **Circumferential**





Hybrid Elastomer Seal: Contract - NASA NAS3-20837 Post Test

Inspection Report: Date: 10/23/81 By: RM Green

Seal Drawing No. ________ Seal Serial No. 13

Garter Spring Tension: 1, ________ lb.; 2, ________ lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 13-1-1	.1629	.1627	.1623
• 13-1-2	.1629	.1622	.1627
• 13-1-3	.1629	.1623	.1626
• 13-2-4	.1628	.1627	.1628
• 13-2-5	.1627	.1626	.1626
• 13-2-6	.1626	.1625	.1627

Static Test Results:

- Light Leakage (%); ________ • Blueing Check (%) ________
- Air Leakage. . . . . . ; Pressure ________ lb/in^2, Flow ________ cc/hr.

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

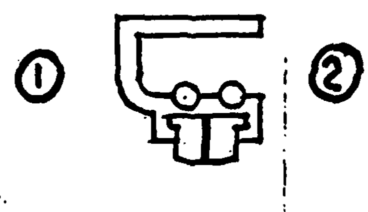
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

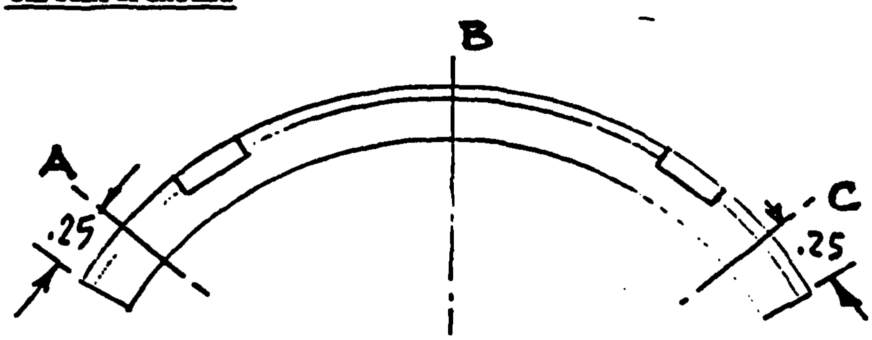
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-13-81 By: RMG

Seal Drawing No. 399808 Seal Serial No. 14

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 14-1-1	.1625	.1621	.1623
• 14-1-2	.1620	.1626	.1626
• 14-1-3	.1628	.1621	.1628
• 14-2-4	.1630	.1629	.1628
• 14-2-5	.1626	.1626	.1628
• 14-2-6	.1623	.1628	.1632

Static Test Results:

- Light Leakage (percent); 0 Bluering 80%
- Air Leakage. . . . . . ; Pressure 2 lb/in^2, Flow 120 cc/h

Carbon Ring Identification: (XX), - X_2 - X_3

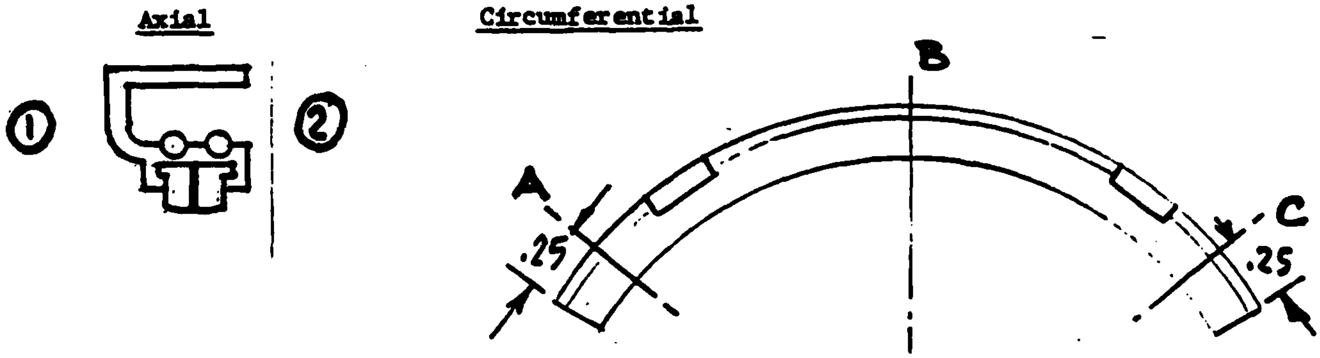
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-25-82 By: RMGreene

Seal Drawing No. 399B08 Seal Serial No. 14

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 14-1-1	.1620	.1615	.1612
• 14-1-2	.1615	.1618	.1617
• 14-1-3	.1620	.1617	.1619
• 14-2-4	.1622	.1625	.1616
• 14-2-5	.1621	.1620	.1621
• 14-2-6	.1615	.1624	.1621

Static Test Results:

- Light Leakage (%): ______ • Blueing Check (%) ______
- Air Leakage. . . . . . ; Pressure ______ lb/in^2, Flow ______ cc/hr

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

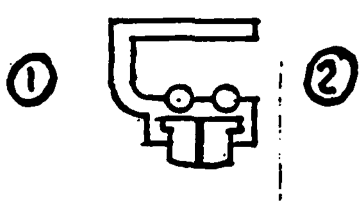
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

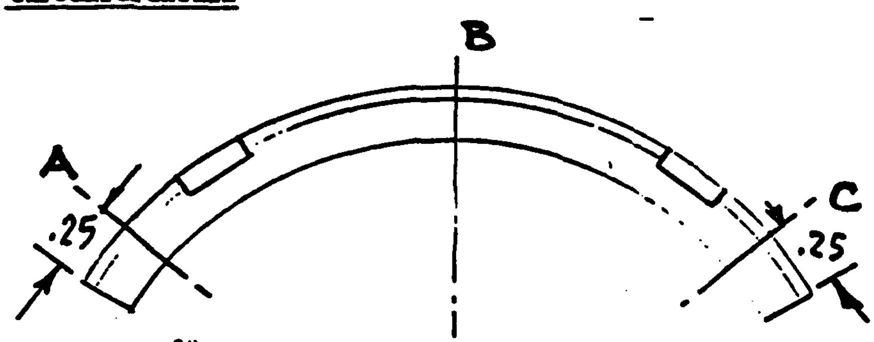
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



Hybrid Elastomer Seal: Contract - NASA NAS3-20837 Runner #1 Taper .0002/.5"

Inspection Report: Date: 10-13-81 By: RMGe

Seal Drawing No. 397B08 Seal Serial No. 16

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 16-1-1	.1629	.1634	.1633
• 16-1-2	.1633	.1630	.1632
• 16-1-3	.1633	.1631	.1633
• 16-2-4	.1625	.1623	.1626
• 16-2-5	.1624	.1622	.1626
• 16-2-6	.1624	.1627	.1623

Static Test Results:

- Light Leakage (percent); 0 Blueing 70%
- Air Leakage. . . . . . ; Pressure 4.5 lb/in^2, Flow 110 cc/hr

---

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

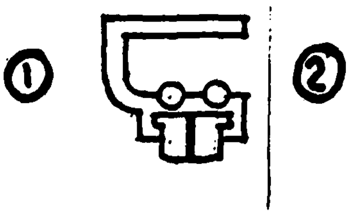
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial



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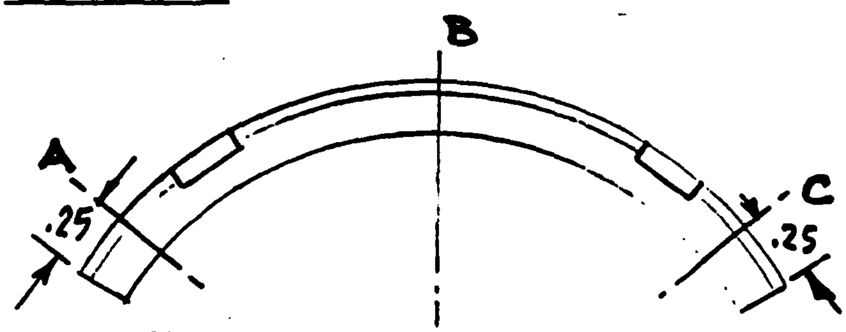


Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 10-28-82 By: RM Green

Seal Drawing No. 399808 Seal Serial No. 16

Garter Spring Tension: 1, ______ lb.; 2, ______ lb.

Carbon Ring Dimensions:

Identification	A	B	C
16-1-1	.1625	.1627	.1622
16-1-2	.1625	.1624	.1624
16-1-3	.1626	.1624	.1625
16-2-4	.1622	.1618	.1622
16-2-5	.1619	.1619	.1622
16-2-6	.1620	.1624	.1623

Static Test Results:

- Light Leakage (%): ______ • Blueing Check (%) ______
- Air Leakage. . . . . . ; Pressure ______ lb/in^2, Flow ______ cc/hr.

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

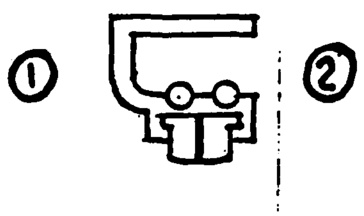
$(XX)_1$ = Set Sequence No.

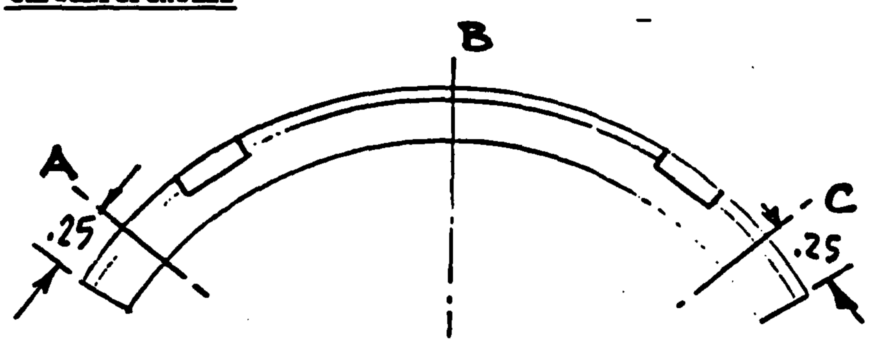
X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial **Circumferential**





Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 4-19-82 By: RMGreen

Seal Drawing No. 399B08 Seal Serial No. 17

Garter Spring Tension: 1, 2 lb.; 2, 2 lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 17-1-1	.1624	.1620	.1625
• 17-1-2	.1618	.1627	.1623
• 17-1-3	.1624	.1623	.1628
• 17-2-4	.1627	.1633	.1634
• 17-2-5	.1633	.1128	.1634
• 17-2-6	.1621	.1628	.1629

Static Test Results:

- Light Leakage (%); 0 • Blueing Check (%) 80
- Air Leakage. . . . . . ; Pressure .25 lb/in^2, Flow 150 cc/hr.

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

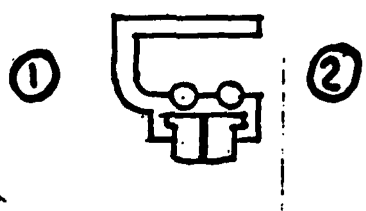
$(XX)_1$ = Set Sequence No.

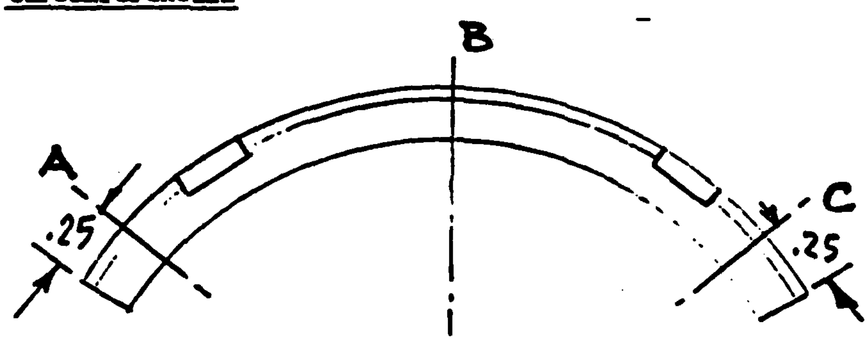
X_2 = Location Position in Seal

X_3 = circumferential Location in Seal

Location Position Identification:

Axial **Circumferential**





Hybrid Elastomer Seal: Contract - NASA NAS3-20837

Inspection Report: Date: 11-2-82 By: RMG[illegible]

Seal Drawing No. ________________ Seal Serial No. 17

Garter Spring Tension: 1, __________ lb.; 2, __________ lb.

Carbon Ring Dimensions:

Identification	A	B	C
• 17-1-1	.1619	.1615	.1616
• 17-1-2	.1614	.1620	.1615
• 17-1-3	.1620	.1618	.1617
• 17-2-4	.1623	.1627	.1625
• 17-2-5	.1623	.1625	.1625
• 17-2-6	.1624	.1626	.1623

Static Test Results:

- Light Leakage (%); __________ • Blueing Check (%) __________
- Air Leakage. . . . . . ; Pressure __________ lb/in^2, Flow __________ cc/hr.

Carbon Ring Identification: $(XX)_1 - X_2 - X_3$

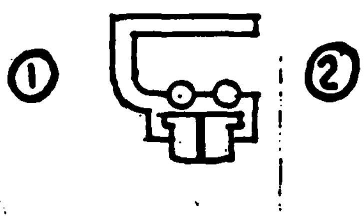
$(XX)_1$ = Set Sequence No.

X_2 = Location Position in Seal

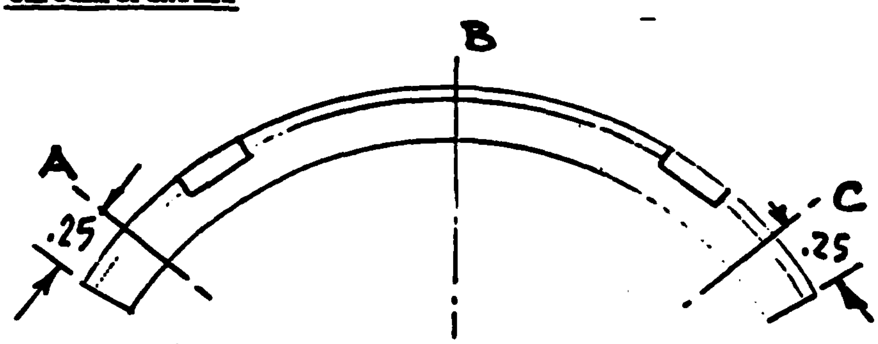
X_3 = circumferential Location in Seal

Location Position Identification:

Axial



Circumferential



APPENDIX D

PROPOSED PROCESS SPECIFICATION FOR THE PRODUCTION OF ELASTOMERIC-HYBRID SEAL

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1. SCOPE

1.1 Scope. This process specification covers the fabrication, assembly and quality assurance provisions necessary for production of elastomeric-hybrid seals for helicopter transmissions. This specification conforms to Form 2 of MIL-S-83490.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal form a part of the specification to the extent specified herein:

SPECIFICATIONS

Federal

TT-S-735	Standard Test Fluids; Hydrocarbon
UU-P-268	Paper, Kraft, Untreated Wrapping
PPP-B-601	Boxes, Wood, Cleated-Plywood
PPP-B-636	Box, Fiberboard
PPP-T-45	Tape, Gummed, Paper, Reinforced and Plain, for Sealing and Securing

Military

MIL-P-4861	Packing, Preformed, Rubber, Packing, Packaging of
MIL-P-116G	Preservation-Packaging, Methods of
MIL-R-25897	Rubber, Fluorocarbon Elastomer, High Temperature, Fluid Resistant
MIL-R-83248	Rubber, Fluorocarbon Elastomer, High Temperature and Compression Set Resistant
MIL-I-45208A	Inspection System Requirements
MIL-C-45662A	Calibration System Requirements

STANDARDS

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-407	Visual Inspection Guide for Rubber Molded Items

2.2 Other Publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

ASTM D297-67T	Rubber Products, Chemical Analysis of
ASTM D395-67	Compression Set of Vulcanized Rubber, Tests for
ASTM D412-68	Tension Testing of Vulcanized Rubber
ASTM D471-66	Change in Properties of Elastomeric Vulcanizates Resulting from Immersion in Liquids, Test for
ASTM D573-67	Accelerated Aging of Vulcanized Rubber by the Oven Method
ASTM D1329-60	Low-Temperature Characterisitics of Rubber and Rubber-Like Materials by a Temperature Retraction Procedure (TR Test)
ASTM D2240-68	Indentation Hardness of Rubber and Plastics by Means of a Durometer, Test for
AMS 2485C	Black Oxide Treatment

Application for copies of ASTM Standards should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103. AMS Standards can be obtained from the Society of Automotive Engineers, 485 Lexington Avenue, New York, New York 10017.

3. REQUIRED PROCEDURES AND OPERATIONS

3.1 Equipment. Equipment necessary to fabricate the several components of the hybrid elastomer seal are those normally found at those suppliers who customarily fabricate such components.

3.2 Materials. Materials of construction shall conform to the following.

3.2.1 Seal Ring Housings. Cold drawn seamless mechanical steel tubing; AISI 1018/1026 or MT-1018.

3.2.2 Molded Elastomer. Fluorocarbon, molded MIL-R-83248 70 durometer shore hardness and shall be of the same composition as the material used for the preproduction sample.

3.2.3 Molded Elastomer Assembly. Black Oxide per AMS 2485C.

3.2.4 Inner Steel Ring Housing. Black Oxide per AMS 2485C.

3.2.5 Carbon Seal Rings. Molded carbon graphite per Pure Carbon P-25; National Carbon CCP-72 or Carbon Technology Inc. Grade 6.

3.2.6 Garter Springs. Stainless steel wire, AISI 302/304.

3.3 Dimensions and Tolerances. Unless otherwise specified, dimensions and tolerances of seal components shall be as specified on the drawing or in the contract or order.

3.4 Required Procedures and Processes. Fabrication of hybrid elastomer seal components shall be performed according to normal commercial practices. Assembly of seal components into the final seal configuration shall not result in damage to any individual component. During assembly, the garter spring tension shall be adjusted according to the following:

a. For 5.481 in. dia. seal at its operating diameter; tension = 2.00 lb
b. For 2.500 in. dia. seal at its operating diameter; tension = 1.75 lb.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may utilize his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Monitoring Procedures for Equipment Used in Process. Equipment used in producing or processing seal components or assembled seals shall be inspected in accordance with Paragraphs 3.3 and 3.4 of MIL-I-45208A.

4.3 Monitoring Procedures for Materials. Assurance that materials used in producing the elastomeric-hybrid seal components comply with specifications shall be implemented by the imposition of Paragraph 3.12 of MIL-I-45208A.

4.4 Classification of Tests. The inspection and testing of the hybrid elastomer seal shall be classified as follows:

a. Preproduction inspection (see 4.5)
b. Quality conformance inspection (see 4.6).

4.5 Preproduction Inspection.

4.5.1. Preproduction inspection of the elastomer shall conform to Paragraph 4.3 of MIL-R-83248.

4.5.2. Preproduction inspection of the remaining seal components shall be considered accomplished when certification of conformance to material specifications has been provided by the supplier.

4.6 Quality Conformance.

4.6.1 Sampling for Inspection. Sampling for quality conformance inspection shall be in accordance with MIL-STD-105, except where otherwise indicated herein. Quality conformance tests are required for all production lots of material.

4.6.1.1 Lot. A lot shall consist of all material of the same identity used in the same production run, from the same batch, and submitted at the same time for inspection.

4.6.2 Quality Conformance Test Samples. Whenever possible, the end item, or specimens cut from the end item, shall be used as the sample. If these items are unsuitable for use as test samples, tests shall be performed on samples of identical composition as that of the end item.

4.6.3 Inspection of Materials and Components. The supplier is responsible for insuring that materials and components used were manufactured, tested, and inspected in accordance with referenced subsidiary specifications and standards to the extent specified, or if none, in accordance with this specification (see 4.1). In the event of conflict, this specification shall govern. Inspection records shall be kept complete and available to the procuring activity at all times.

4.6.3.1 Inspection of Molded Elastomer. The supplier shall inspect the molded elastomer in accordance with Paragraph 4.4 of MIL-R-83248.

4.6.3.2 Inspection of Remaining Seal Components. The supplier shall inspect seal components in accordance with inspection level II of MIL-STD-105 and the ALQ related to percent defective shall be 1.5.

4.7 Test Methods. Each fully assembled hybrid elastomer seal shall be tested for performance by the following procedure.

> Seal performance shall be determined by mounting the seal in a seal test fixture which can be pressurized. The accuracy of the seal bore shall be determined by a combination of means which includes air leakage checks, light tightness and blueing procedures to get a qualitative measure of the percentage of contact area. The shaft diameter for these checks shall be round, within 0.000050 inch with taper less than 0.0002 inch per inch.

4.7.2 Acceptance Critera shall be:

1. Air leakage, less than 150 cc/hr at 3 psig
2. Light tightness, no light leakage shall be discernible with the unaided eye
3. Blueing procedure, a qualitative measure of the percent of coverage of 75% shall be acceptable.

5. NOTES

5.1 Intended Use. The seals procured to this specification are intended for use in military helicopter transmissions where resistance to jet fuel, synthetic engine lubricants or petroleum-based hydraulic fluids is required. In addition, the inclusion of carbon-graphite sealing elements provides improved speed capability for advanced transmission designs.